Delaware's Greenhouse Gas Inventory 2018

DNREC DIVISION OF
AIR QUALITY

Department of Natural Resources and Environmental Control
Division of Air Quality
September 2021

Quick Summary

Economic Sector	2018 GHG Emissions[a]	Projection to 2030 (future)	Projection to 2050 (future)
Overall GHG Emissions	• Increase by 1.02 MmtCO$_2$e (6.4%) from 2017 GHG emissions	• Minor decrease by 0.14 MmtCO$_2$e (0.8%) from 2018 GHG emissions	• Increase by 1.36 MmtCO$_2$e (8.1%) from 2018 GHG emissions
Electric Power[b]	• Increase of 0.30 MmtCO$_2$e (7.7%) from 2017 GHG emissions • Second largest sector of GHG emissions in DE	• Decrease by 0.44 MmtCO$_2$e (5.3%) from 2018 GHG emissions • Third largest sector of GHG emissions in DE	• Decrease by 0.31 MmtCO$_2$e (7.4%) from 2018 GHG emissions • Third largest sector of GHG emissions in DE
Transportation	• Increase by 0.23 MmtCO$_2$e (4.8%) from 2017 GHG emissions • Largest sector of GHG emissions in DE	• Decrease by 0.23 MmtCO$_2$e (4.5%) from 2018 GHG emissions • Largest sector of GHG emissions in DE	• Decrease by 0.32 MmtCO$_2$e (6.3%) from 2018 GHG emissions • Second largest sector of GHG emissions in DE
Industrial	• Minor increase by 0.05 MmtCO$_2$e (1.1%) from 2017 GHG emissions • Third largest sector of GHG emissions in DE	• Increase by 0.18 MmtCO$_2$e (4.5%) from 2018 GHG emissions • Second largest sector of GHG emissions in DE	• Increase by 1.46 MmtCO$_2$e (36.3%) from 2018 GHG emissions • Largest sector of GHG emissions in DE
Residential[c]	• Increase by 0.24 MmtCO$_2$e (26.5%) from 2017 GHG emissions	• Negligible decrease by <0.01 MmtCO$_2$e (0.4%) from 2018 GHG emissions	• Increase by 0.13 MmtCO$_2$e (11.3%) from 2018 GHG emissions
Commercial[c]	• Increase by 0.22 MmtCO$_2$e (19.4%) from 2017 GHG emissions	• Increase by 0.16 MmtCO$_2$e (11.9%) from 2018 GHG emissions	• Increase by 0.37 MmtCO$_2$e (27.4%) from 2018 GHG emissions

Economic Sector	2018 GHG Emissions[a]	Projection to 2030 (future)	Projection to 2050 (future)
Agricultural	• Decrease by 0.01 $MmtCO_2e$ (2.2%) from 2017 GHG emissions	• Increase by 0.04 $MmtCO_2e$ (7.3%) from 2018 GHG emissions	• Increase by 0.06 $MmtCO_2e$ (10.3%) from 2018 GHG emissions
Waste Management	• Negligible decrease by <0.01 $MmtCO_2e$ (0.3%) from 2017 GHG emissions	• Decrease by 0.06 $MmtCO_2e$ (12.7%) from 2018 GHG emissions	• Decrease by 0.03 $MmtCO_2e$ (5.9%) from 2018 GHG emissions

[a] Gross GHG emissions; land-use, land-use change, forestry not included
[b] Emissions associated with electricity consumption included for 2017 as well to give direct comparison
[c] Change in methodology for HFC emissions estimation contributed, in part, to increase

Contents

Introduction

This emissions inventory report was prepared by the Department of Natural Resources and Environmental Control (DNREC), Division of Air Quality for Delaware to present the findings of the 2018 Greenhouse Gas (GHG) emissions inventory and account for GHG emissions and sinks[1] in the state of Delaware. The inventory includes Delaware GHG emissions from 1990 to 2018 as well as emission projections from 2019 to 2050 in a business as usual (BAU) scenario. In addition to the emissions data, this report provides information on emission sources and activities, as well as inventory methods.

Delaware's anthropogenic[2] GHG emissions were estimated using a set of generally accepted principles and guidelines as well as protocols for state GHG emissions inventories established by the U.S. Environmental Protection Agency (EPA) and International Organization for Standardization (ISO).

Greenhouse gas emissions from Delaware's sources are presented in this report by using a common metric, carbon dioxide equivalents (CO_2e), which accounts for the relative contributions of each gas to global average radiative forcing on a Global Warming Potential (GWP) weighted basis. The emissions estimates in this report are represented in million metric tons of carbon dioxide equivalents ($MmtCO_2e$).

To develop the annual emissions inventory of GHGs from Delaware for the period of 1990 to 2018 with projections from 2019 to 2050, emissions estimations were performed by using the U.S. EPA's State Inventory Tool (SIT) and projection tool (PT). The SIT and PT consist of Microsoft Excel® spreadsheets, which facilitate the collection of activity data (information on the extent to which human activity takes place) and emission factors (coefficients that quantify emissions or removal per unit activity)[3] that are based on economic activities[4] in Delaware. Where applicable, Delaware specific data have been used to supplement the standard default data provided by the top-down approach of the EPA SIT sector modules. Projections of GHG emissions are estimated by utilizing the U.S. Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2020[5] data as well as other economic data that are used to predict GHG emissions. It is important to understand that the data presented in this GHG inventory report are estimates and projections that include a degree of uncertainty. The modeling and analysis provide a tool to assess the current state and possible projection of future GHG emissions in Delaware.

[1] Sinks: Removal or sequestration of greenhouse gases from the atmosphere.
[2] The term "anthropogenic", in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities (IPCC/UNEP/OECD/IEA 1997)
[3] 2006 IPCC Guidelines for National Greenhouse Gas Inventories
[4] This includes fossil fuel combustion, industrial processes, agricultural activities, and waste management
[5] Annual Energy Outlook 2020, U.S. Energy Information Administration

Updates from the 2017 Greenhouse Gas Inventory Report

The BAU case in the 2018 GHG Inventory has been updated to include estimated emission reductions from policies that are currently active and established in Delaware. These policies include Delaware's renewable portfolio standards (RPS) and prohibitions on certain hydrofluorocarbons (HFC) in specific end-uses. Delaware's RPS were established by the Renewable Energy Portfolio Standards Act (26 Del.C. § 351 – § 364)[6]. The standards were updated and signed into law in February 2021, mandating that utilities derive 40% of their energy from renewable sources by 2035. Delaware adopted a regulation (7 DE Admin Code 1151) on the prohibition of certain HFCs in specific end-uses in March 2021[7]. The effective dates for prohibition vary by HFC and end-use, with the earliest effective dates occurring in September 2021.

Baseline emissions for the 2018 GHG Inventory are considered at 2005 levels. The state of Delaware has targeted GHG emissions reductions of 26-28% below 2005 levels by 2025. This target is guided by Delaware's original commitment as a member state of the U.S. Climate Alliance (USCA)[8]. The 2018 GHG Inventory assesses the trajectory of GHG emission projections in relation to this reduction in the BAU case.

Greenhouse gas emissions associated with electric power consumption are now included in the overall assessment of the electric power sector. The methodology for estimating the GHG emissions and projections associated with electricity consumption is described in the **Electric Power Sector** section of this report. These emissions were included to provide a more holistic depiction of GHG emissions associated with the electric power sector. Typically, between 30-55% of the electricity used in Delaware is generated outside of the state. Many other states use this approach, making this GHG inventory more consistent and accurate. Electricity consumption-based GHG emissions are not distributed to each sector; only the total is included in the analysis of the electric power sector. Greenhouse gas emission reductions associated with Delaware's RPS are estimated using the required renewable energy percentages per year. As the current RPS is set through 2035, the RPS requirement for years 2036-2050 is held constant at 40%.

The residential and commercial sectors have been combined in this report under an overall section for the buildings sector. Under this section, there is a brief analysis for the total sector as well as analyses for the individual residential and commercial sectors.

An additional analysis was conducted to disaggregate energy-related GHG emissions in the following sectors: transportation, industrial, residential, and commercial. In each of these sectors, relevant breakdowns have been estimated for particular end use sources of GHG emissions. For example, in the transportation sector, end use emissions have been estimated by vehicle type category. It should be noted, however, that for each of the analyses in each

[6] Renewable Energy Portfolio Standards; available: https://dnrec.alpha.delaware.gov/climate-coastal-energy/renewable/portfolio-standards/
[7] 1151 Prohibitions on Use of Certain Hydrofluorocarbons in Specific End-Uses; available: https://regulations.delaware.gov/AdminCode/title7/1000/1100/1151.pdf
[8] Delaware Joins U.S. Climate Alliance to Uphold Goals of Paris Agreement; available: https://news.delaware.gov/2017/06/05/delaware-joins-u-s-climate-alliance-to-uphold-goals-of-paris-agreement/

sector, GHG emissions by end use are only assessed for estimates[9] and not emission projections. The current analyses were conducted using estimates based on a referenced dataset, supplemental analysis, or a combination of these resources. Please refer to the section for each economic sector for additional details.

The use of HFCs in refrigeration, air-conditioning, and other applications has been rapidly increasing. Hydrofluorocarbons are high-GWP GHGs that can have potent climate related effects in the atmosphere. In collaboration with the California Air Resources Board (CARB), the USCA developed an emissions inventory tool for estimating HFC emissions at the state level. The California Air Resources Board estimated HFC emissions in California under a no HFC policy scenario to determine end-use HFC emission estimates per person, per household, or per vehicle. The 2016 Delaware GHG inventory[10] report provides more detail on the HFC inventory tool and how it was used in that GHG inventory. The 2017 Delaware GHG inventory used a hybrid approach[11] to estimate HFC emissions by sector; however, the USCA/CARB HFC inventory tool has undergone improvements and additional quality control. The 2018 GHG Inventory report will use the estimates from this tool. The USCA/CARB HFC inventory tool provides emissions projections through 2030. For projections for years 2031-2050, HFC emissions were linearly forecasted using projection trends from years 2025-2030. Hydrofluorocarbon emissions are estimated and projected for the residential, commercial, industrial, and transportation sectors.

The HFC inventory tool from USCA and CARB also provides an emission projections case that considers HFC prohibitions associated with U.S. EPA Significant New Alternatives Policy (SNAP) rules 20 and 21[12]. While these rules were vacated, Delaware's HFC prohibition regulation adopted specific requirements from SNAP rules 20 and 21. Emission reductions were estimated using the SNAP case emission projections from the USCA/CARB tool as applicable to Delaware.

The land-use, land-use change, and forestry (LULUCF) module of the SIT has been updated with the U.S. EPA's release of the 2018 base year modules. The updated LULUCF module uses updated data from the U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA). The data were updated as described in a report published through the USFS to identify GHG emissions and removals from forest land, woodlands, and urban trees nationwide[13]. The updated data are available on the USFS website and were incorporated to the LULUCF SIT module. Two additional capabilities were presented with the updated data. First, using the updated data, the USFS presented new estimates for historical GHG emissions and removals in the land sector. However, in the annual GHG inventory report for Delaware, historical data are typically held constant. Second, the report presents the data further disaggregated based on

[9] In some sectors, this refers to the full time-series of 1990 to 2018, in other sector(s) analysis or data may not have been available for the full time series but are provided according to data availability.
[10] Delaware's 2016 Greenhouse Gas Inventory (2019); available: http://www.dnrec.delaware.gov/Air/Documents/2016-de-ghg-inventory.pdf
[11] Delaware's 2017 Greenhouse Gas Inventory (2020); available: http://www.dnrec.delaware.gov/Air/Documents/2017-DE-GHG-Inventory.pdf
[12] SNAP Regulations, U.S. EPA; available: https://www.epa.gov/snap/snap-regulations
[13] Domke, GM, et al., Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2018; available: https://www.nrs.fs.fed.us/pubs/59852

specific land type and land type conversion to provide a deeper analysis. The data presented in this report retain historical estimates for the LULUCF sector. Estimates for 2018 will use the new methodology, while projections will hold the 2018 sink value constant (as was done in previous reports). At this time, the additional analyses and updated historical data will not be added, though they may be considered for future GHG inventories.

The coronavirus (COVID-19) pandemic had an unprecedented and significant impact on the livelihood of Delawareans, the economy, and industry in the year 2020. The U.S. EPA projection tool for GHG emissions uses assumptions and projected economic data from the U.S. EIA AEO 2020. As such, the impact of the COVID-19 pandemic has not been captured in this inventory report for 2020 and beyond. For context, the U.S. EIA has recently released the 2021 edition of the AEO[14]. Under the reference case, it is expected that U.S. energy consumption returns to pre-pandemic levels by 2029. The impact of the COVID-19 impact will be more accurately captured in future GHG inventory reports that will use updated data.

Sources of Greenhouse Gas Emissions and Trends

The 2018 GHG inventory estimates GHG emissions from various sources across economic sectors in Delaware. The economic sectors that were assessed are electric power[15], transportation, industrial, residential and commercial buildings, agriculture, waste management, and land-use, land-use change, and forestry (LULUCF). Particular methodologies and activity data, such as fossil fuel combustion, were analyzed to estimate GHG emissions from each of the sectors. As explained in the **Updates** section, reductions associated with active policies in Delaware are accounted for in the BAU assessment. Particularly, GHG emission reductions associated with Delaware's RPS and HFC regulation are included.

In 2018, Delaware's gross total GHG emissions were estimated at 16.89 MmtCO_2e, which represents approximately 0.25% of the national gross GHG emissions (U.S. gross total was 6,677 MmtCO_2e in 2018)[16]. Figure 1 shows the historical gross GHG emissions in Delaware from 1990 to 2018. The overall figure presents a difference relative to that presented in the 2017 GHG inventory report[17]. The main reasons for this difference are the inclusions of electricity consumption-based emissions and reductions associated with current policies. Further, the 2018 GHG inventory uses a different method to estimate HFC emissions than the 2017 GHG inventory (as detailed in the **Updates** section), leading to an increase in estimated HFC emissions in the residential and commercial buildings sector. While including these changes in methodology, an increase in GHG emissions was realized in 2018 in Delaware. The inclusion of electricity consumption-based emissions causes an increase in emissions in all years of the GHG inventory. The demand for electricity consumption in Delaware met with imported electricity varies between 30% and 55% in a given year. Additional detail on the methodology and context of electricity consumption is provided in the section on the electric power sector.

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[14] Annual Energy Outlook 2021, U.S. Energy Information Administration; available: https://www.eia.gov/outlooks/aeo/
[15] Including electricity consumption-based GHG emissions
[16] U.S. EPA: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018; available: https://www.epa.gov/ghgemissions/ inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018
[17] Delaware's 2017 Greenhouse Gas Inventory (2020); available: http://www.dnrec.delaware.gov/Air/Documents/2017-DE-GHG-Inventory.pdf

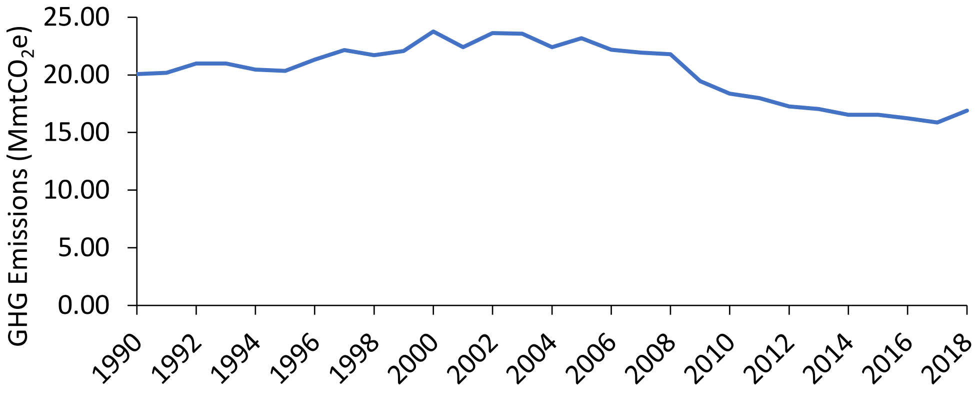

Figure 1. Gross GHG emissions from 1990 to 2018 in Delaware

Figure 2 shows the breakdown of GHG emissions (in $MmtCO_2e$) in 2018 by economic sector, as well as end uses (where available). The largest source of GHG emissions in Delaware in 2018 was the transportation sector, which represented 30% of the gross GHG emissions. When including electricity consumption-based emissions, the electric power sector is the second largest contributor of GHG emissions. Greenhouse gas emissions from the electric power sector in 2018 accounted for 25% of the gross total in Delaware. The electric power sector was split roughly in half for emissions from in-state generation (13% of total) and imported power for consumption (12% of total). The industrial sector accounted for 24% of the total GHG emissions in the state in 2018 (third highest sector). The buildings sector accounted for a total of 15% of statewide GHG emissions, with 7% from the residential sector and 8% from the commercial sector. Finally, the waste management and agriculture sectors each contributed 3% to the total GHG emissions in 2018.

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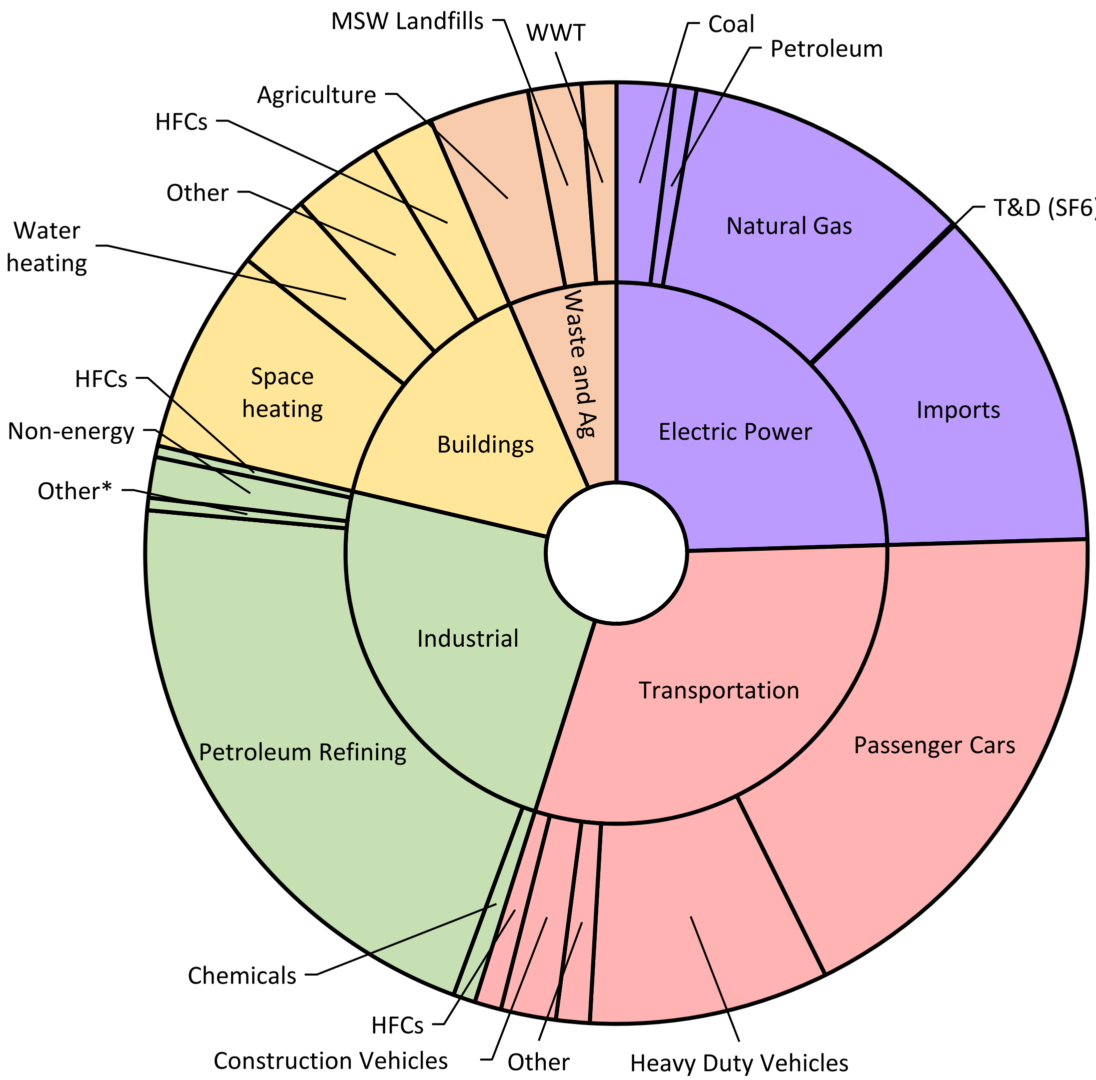

Figure 2. Gross GHG emissions in Delaware in 2018 broken out by sector and end-use (where applicable)

The presented end uses in Figure 2 give a high-level overview of disaggregated sources of GHG emissions for the energy-related sectors. Methodology and data sources for each end use estimate is provided in the relevant sector section. The largest emission sectors are generally made up of one to two significant end uses. For example, the majority of GHG emissions in the transportation sector are sourced from on-road vehicles, such as passenger cars and heavy-duty vehicles. Greenhouse gas emissions estimated in the industrial sector are primarily sourced from operations at the refinery. For further detail on methodology, please refer to the relative sections for each sector.

The overall trends of GHG emissions in each of the sectors can be seen in Figure 3. In Figure 3, the overall electric power sector is broken out to emissions from in-state generation (labeled electric power) and electricity consumption. Emissions from each have been trending downwards in recent years, likely caused by factors such as decreasing demand for electricity as well as fuel shifting to power generation from natural gas as opposed to coal. In addition, emission reductions associated with Delaware's RPS contribute to the declining trends in electric power sector emissions. Transportation sector GHG emissions have remained fairly constant since 1990. The industrial sector had a sharp decline in 2009 which was primarily caused by the economic recession and the refinery shutting down operations. Each other sector had experienced minor fluctuations since 1990, with the residential and commercial sectors slightly trending upwards from increased HFC emissions. The driving force for GHG emissions was largely energy consumption in the relevant economic sectors. Energy-related activities – specifically, fossil fuel combustion – were the largest source of GHG emissions in 2018 as they represented 88.7% of gross GHG emissions in Delaware[18].

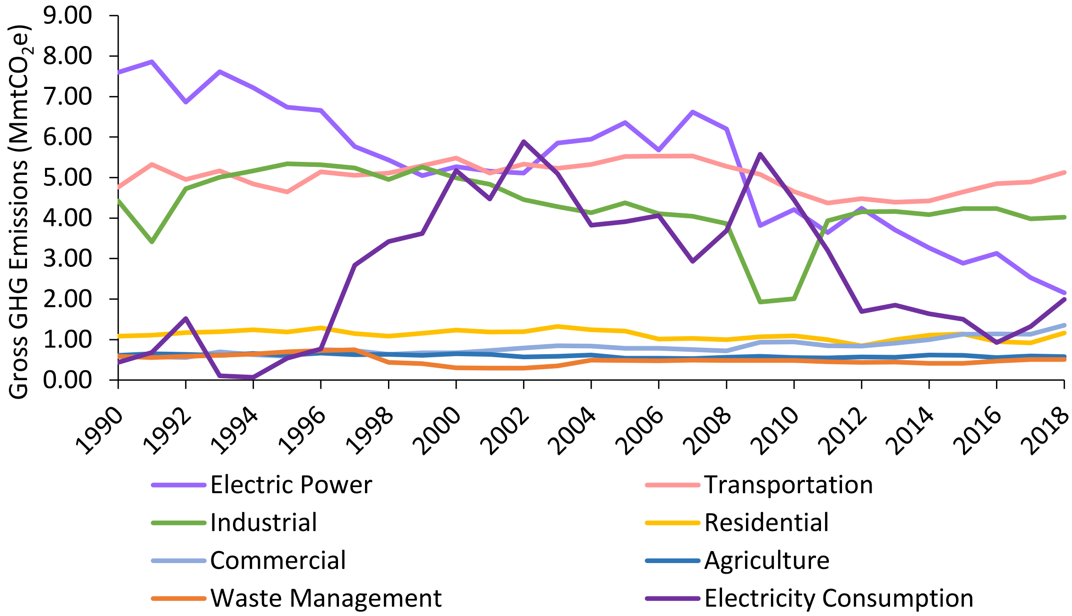

Figure 3. Gross GHG emission trends in Delaware by economic sector from 1990 to 2018

Net GHG emissions are calculated by including the LULUCF sector to the total emissions. The LULUCF sector can act as a sink for CO_2 emissions (i.e., it estimates the removal of CO_2 emissions from the atmosphere by the land sector). In this analysis, the LULUCF sector is actually a source of emissions between 1990 and 1998 (excluding 1997), as shown in Figure 4. In 2018, the total net GHG emissions were 16.03 $MmtCO_2e$, which represents an estimated offset from the LULUCF sector of about 0.86 $MmtCO_2e$, or 5.1% of the total gross GHG emissions. As stated in the **Updates** section, the SIT module for the LULUCF sector was updated with more current FIA data from the USFS. Further assessment of the LULUCF sector is provided in the sector's section of this report.

[18] This percentage includes emissions associated with electricity consumption.

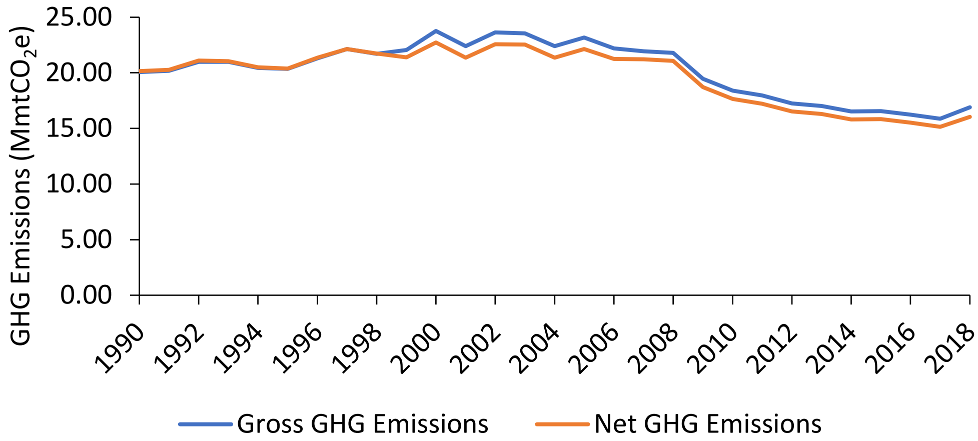

Figure 4. Comparison of gross and net GHG emissions in Delaware from 1990 to 2018

Business as Usual Greenhouse Gas Emission Projections

Greenhouse gas emissions in Delaware are projected to increase from 2019 to 2050. Figure 5 shows that GHG emissions steadily increase after 2019. There are three important differences to consider in this projection analysis compared to that performed in the 2017 GHG inventory report. First, as explained in the **Updates** section of this report, the BAU emissions case includes emission reductions associated with policies that are currently active in Delaware. Second, electricity consumption-based GHG emissions are accounted for in the projections. Third, HFC emissions were previously assumed to be a constant value after 2030. As explained in the **Updates** section of this report, HFC emissions post-2030 were linearly extrapolated. Total gross GHG emissions are projected to be essentially constant from 2018 in 2030 (16.76 $MmtCO_2e$) but increase by 8.1% in 2050 (18.26 $MmtCO_2e$). It is important to note that this projection is just one tool to consider the future of GHG emissions in Delaware. The uncertainty associated with these projections increases as the projection period goes further out.

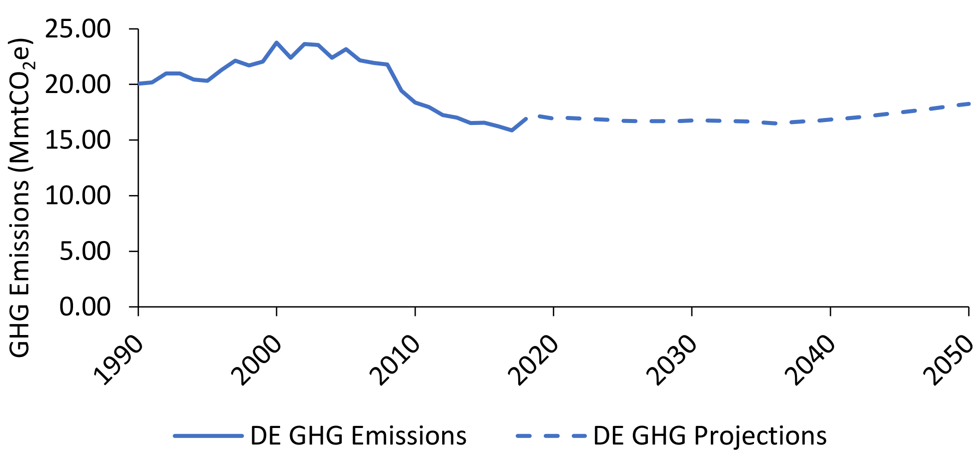

Figure 5. Gross GHG emissions and projections in Delaware from 1990 to 2050

The breakdown of gross GHG emissions projected in Delaware in 2030 and 2050 is shown in Figure 6. The transportation sector remains the largest source of GHG emissions in 2030, followed by the industrial sector. The combined electric power sector (in-state generation and consumption-based emissions) is the third highest emitting sector. Delaware's RPS continues to provide emission reductions in the electric power sector. There is a shift in the relative composition of sectoral contributions to the statewide GHG emissions in 2050. Notably, the industrial sector becomes the largest source of GHG emissions in Delaware, while the transportation sector becomes the second largest source. The total electric power sector (in-state generation and consumption-based emissions) remains the third highest emitting sector. Projected industrial sector growth in the U.S. EIA AEO 2020 is likely the main cause for this shift. The relative contributions from the remaining sectors show as unchanged from 2030.

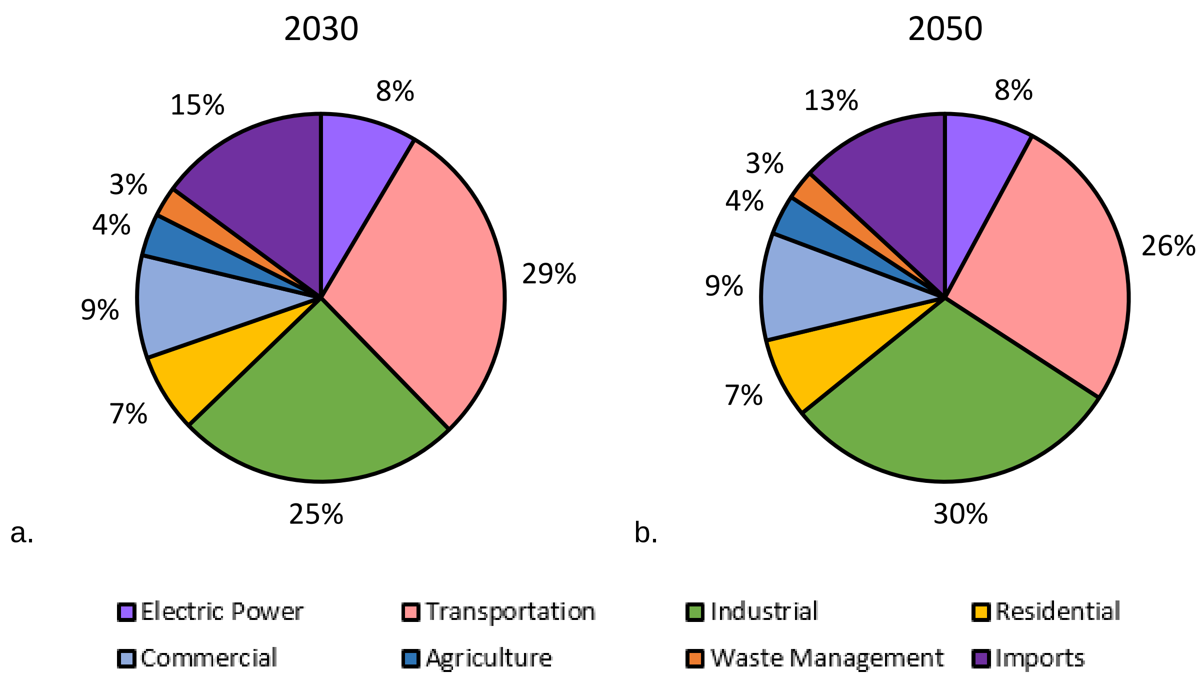

Figure 6. Gross GHG projections in Delaware by sector in (a) 2030 and (b) 2050

The GHG emissions estimates and projections by sector from 1990 to 2050 are shown in Figure 7. The greatest increase in GHG emissions over the time period is in the industrial sector. Again, the U.S. EIA AEO 2020 shows projected increases fossil fuel consumption in the industrial sector that relate to increased GHG emissions. Greenhouse gas emissions from in-state electricity generation show a declining trend through 2035 and then flatline through 2050. This can be expected as the RPS in Delaware is held constant after 2035. Projected emissions from in-state electricity generation fall below those in the commercial sector. The transportation sector shows a declining trend in GHG emissions, but emissions appear to flatline as the projection approaches 2050. The residential and commercial sectors each see increases in GHG emissions throughout the projection period. This increase is in part caused by the projected HFC emissions in these sectors. Emission reductions associated with Delaware's HFC prohibitions do not apply to the residential sector. In the case of the commercial sector, HFC emissions are partly mitigated; however, energy-related GHG emissions are also expect to rise, which can be associated with growth in the sector as projected in the U.S. EIA AEO 2020. The agriculture and waste sectors are projected to remain constant through 2050.

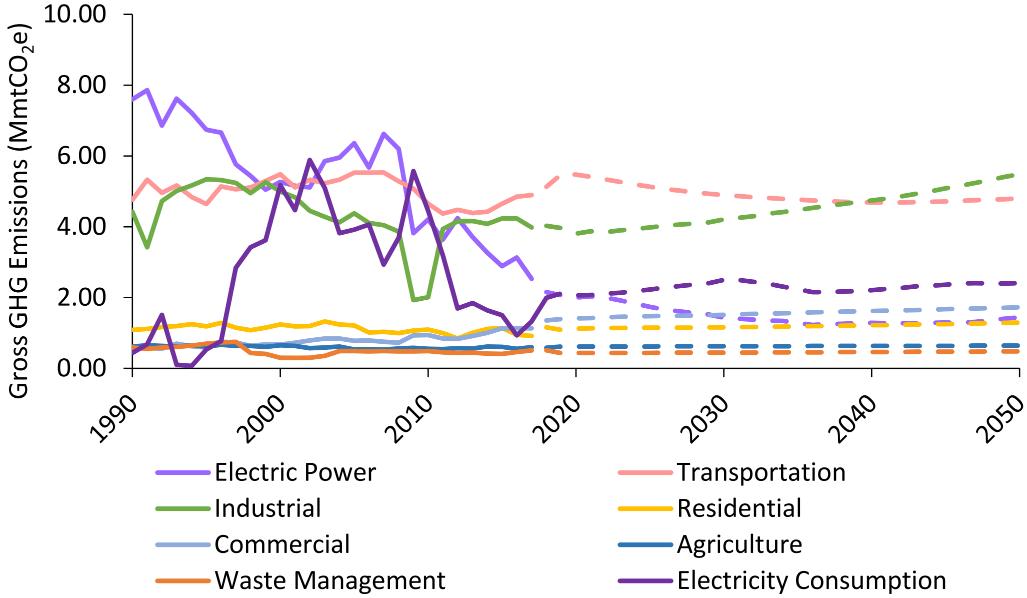

Figure 7. Gross GHG emission and projection trends by economic sector in Delaware from 1990 to 2050

Baseline Greenhouse Gas Emission Projections

Greenhouse gas emissions from 2005 were considered as the baseline to assess reductions in Delaware. Gross GHG emissions in Delaware were estimated at 23.19 $MmtCO_2e$ in 2005. As the current target for Delaware's GHG emissions reduction is 26-28% of 2005 levels by 2025, emissions in 2025 should be between 16.69 and 17.16 $MmtCO_2e$. Figure 8 shows the gross GHG emission estimates and projections in Delaware from 1990 to 2050. The baseline emissions are shown as a reference as if no policy reductions were accounted. The BAU case shown includes respective reductions from Delaware's RPS and HFC prohibitions regulation (denoted as HFC reg). Emission reductions associated with the RPS are the bulk of reductions in the BAU case, while the reduction contribution from the HFC prohibitions is less. Notably, Figure 8 shows that the 26% reduction target is achieved by 2025 when accounting for these policy reductions. Without these reductions, the target is not achieved, showing the necessity of these policies to continue to mitigate the harmful effects from climate change[19]. After 2035, emission increases begin to overcome the reductions achieved through policy. The RPS requirements are held constant after 2035 and can no longer keep up with the emission increases. By about 2044, the emission reduction from 2005 levels no longer achieves 26%. Further policy may be needed to reduce GHG emissions throughout 2050 to continue to avoid harmful impacts from climate change.

[19] Understanding Climate Change; available: https://dnrec.alpha.delaware.gov/climate-coastal-energy/climate-change/

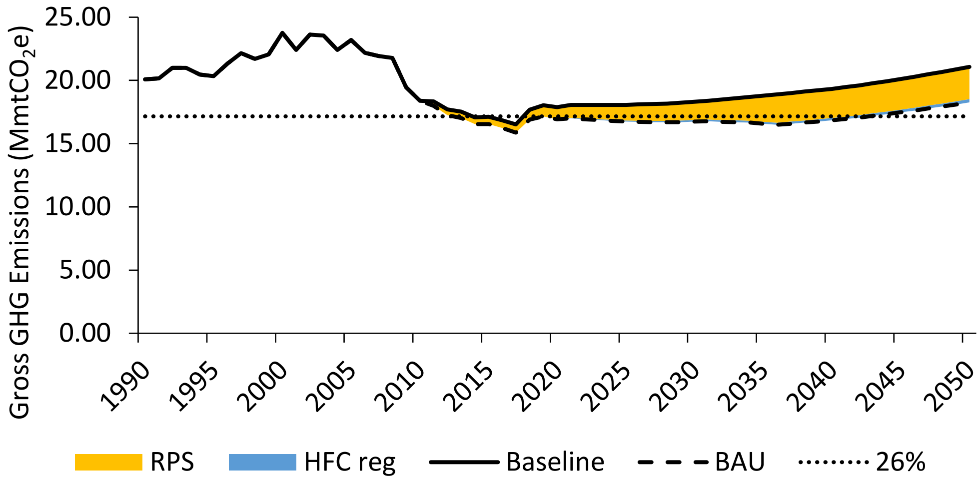

Figure 8. Baseline and BAU GHG emission estimates and projections in Delaware from 1990-2050, showing emissions reductions associated with currently active policies

Greenhouse Gas Emissions by Gas Type

The 2018 GHG inventory estimated emissions for the following GHGs, per the Greenhouse Gas Protocol[20]: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

Figure 9 presents the gross GHG emissions by gas in 2018. Carbon dioxide emissions represent the most abundant type of GHGs with about 88% of the total gross GHG emissions in Delaware. Methane is the next highest emitted type of GHG at about 4.8% of the total in 2018. Nitrous oxide and the combined contribution of the fluorinated gases (HFCs, PFCs, and NF_3) each contributed about 3% of the total GHG emissions in 2018 in Delaware. Sulfur hexafluoride emissions associated with the transmission and distribution (T&D) of electricity were minimal.

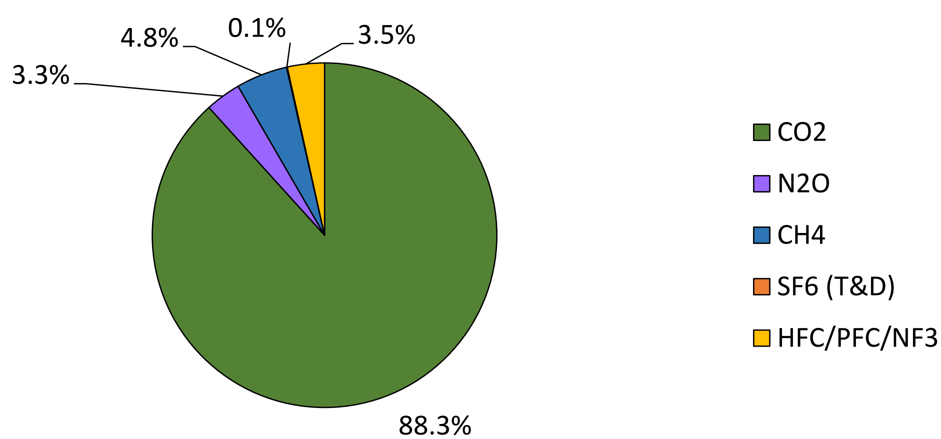

Figure 9. Gross GHG emissions by gas type in 2018 in Delaware (emissions in units of $MmtCO_2e$)

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[20] Greenhouse Gas Protocol, February 2013, Required Greenhouse Gases in Inventories

The relative contributions projected per GHG type in Delaware in 2030 and 2050 are shown in Figure 10. Carbon dioxide is projected to remain around 87% of the total GHG emissions in Delaware through 2050. Relative contributions of CH_4 and N_2O show slight increases towards the total GHG emissions. This increase is likely an effect of emissions reductions associated with Delaware's RPS, as CO_2 is the primarily reduced GHG. The combined emissions of HFCs, PFCs, and NF_3 are projected to become the second highest contributing types of GHGs. Reductions associated with Delaware's HFC prohibitions provide some mitigation after they come into effect; however, current trends show emissions of HFCs are rapidly growing.

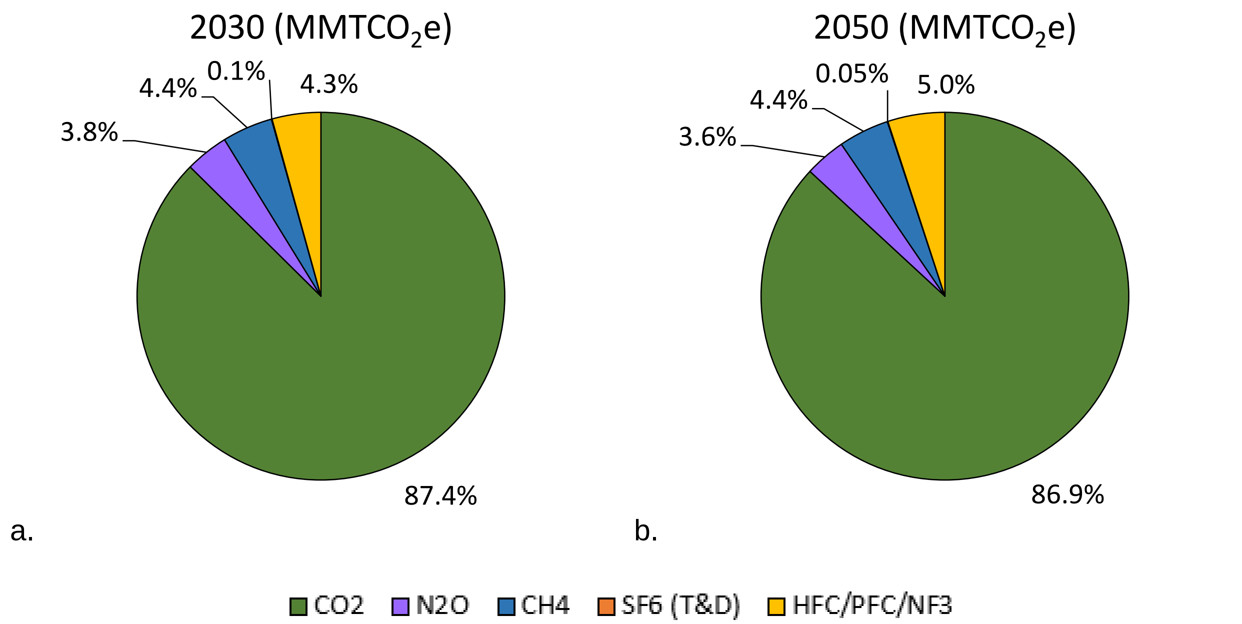

Figure 10. Gross GHG emissions projected by gas type in Delaware in (a) 2030 and (b) 2050 (emissions in units of $MmtCO_2e$)

Greenhouse Gas Emissions per Person

Another option to present Delaware's GHG emissions is to analyze the data by state population on a per capita basis. This is useful when comparing emissions from one state to another. Many factors contribute to the amount of GHG emissions per capita. According to the U.S. EIA, factors such as climate, the structure of the economy, population density, energy sources, building standards, and explicit state policies can impact GHG emissions. Per the U.S. EIA analysis, only CO_2 emissions associated with in-state energy-related activities (i.e., fossil fuel combustion) were included. In 2018, Delaware ranked 31st in energy-related CO_2 emissions per capita at 13.1 metric ton CO_2e (mtonCO_2e) per person[21]. The average energy-related emissions per capita among all states in 2018 was 16.2 mtonCO_2e/person, which is about 24% higher than Delaware.

Figure 11 shows the trend of per capita GHG emissions in Delaware and includes GHG emissions and projections from all sectors (including electricity consumption-based emissions).

[21] U.S. EIA, Energy-Related CO_2 Emission Data Tables; available: https://www.eia.gov/environment/emissions/state/

Annual per capita GHG emissions decreased by 42% from 30.0 mtonCO_2e/person in 1990 to 17.5 mtonCO_2e/person in 2018. The significant decrease in per capita GHG emissions from 1990 to 2018 can be attributed to a number of factors including energy efficiency in multiple economic sectors and switching from a more carbon intensive fuel such as coal to a less carbon intensive fuel such as natural gas.

Projected GHG emissions per capita are expected to have a minor decrease from 17.7 mtonCO_2e/person annually in 2019 to 16.3 mtonCO_2e/person in 2050. While emissions associated with electricity use may be expected to increase with population, it is likely that Delaware's RPS mitigates some of these increases. Annual GHG emissions per capita flatline throughout the projection period, which may be the result of the RPS and energy efficiency keeping up with the potential increases in GHG emissions associated with population growth.

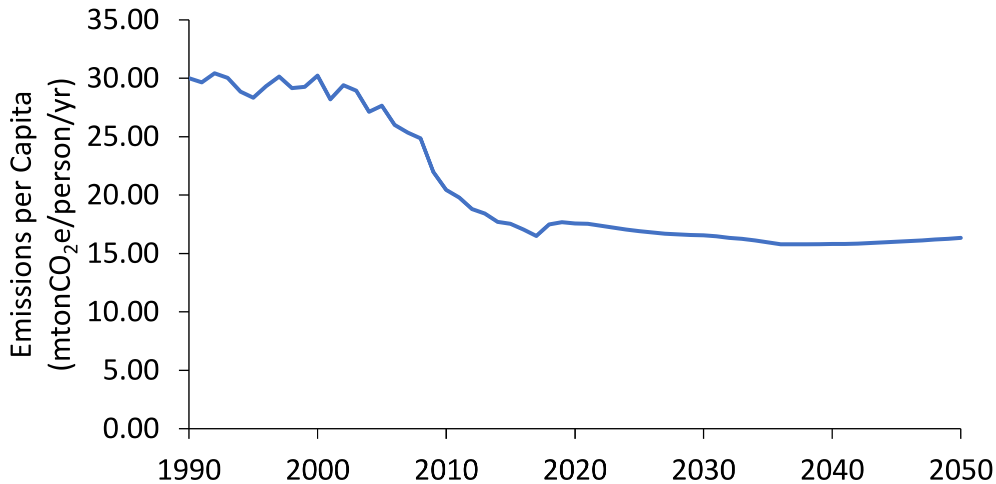

Figure 11. Annual gross GHG emissions per capita in Delaware from 1990 to 2050

Greenhouse Gas Emission Trends by Economic Sectors

The 2018 GHG emissions inventory characterized GHG emissions into eight economic sectors across Delaware. A summary table of the business as usual GHG emission estimates and projections is provided as Table 1. The emission trends and analytical findings of each of these sectors are summarized in the following sections. FFC stands for “fossil fuel combustion.”

Table 1. Summary table of business as usual GHG emissions estimates and projections in Delaware

	1990	2005	2018	2030	2050
Electric Power (in-state generation)	**7.60**	**6.36**	**2.15**	**1.43**	**1.44**
CO_2 from FFC	7.49	6.29	2.14	1.42	1.43
N_2O from FFC	0.03	0.03	<0.01	<0.01	<0.01
CH_4 from FFC	<0.01	<0.01	<0.01	<0.01	<0.01
SF_6 from T&D	0.08	0.04	0.01	0.01	0.01
Electricity Consumption	**0.43**	**3.91**	**1.99**	**2.50**	**2.40**
CO_2 from FFC	0.43	3.90	1.99	2.49	2.40
N_2O from FFC	<0.01	0.02	<0.01	<0.01	<0.01
CH_4 from FFC	<0.01	<0.01	<0.01	<0.01	<0.01
Transportation	**4.76**	**5.52**	**5.12**	**4.89**	**4.80**
CO_2 from FFC	4.53	5.15	4.93	4.72	4.65
N_2O from FFC	0.20	0.17	0.04	0.06	0.06
CH_4 from FFC	0.03	0.01	0.01	0.01	0.01
HFCs	<0.01	0.19	0.15	0.11	0.08
Industrial	**4.42**	**4.38**	**4.02**	**4.20**	**5.48**
CO_2 from FFC	4.04	3.93	3.71	3.91	5.16
N_2O from FFC	0.01	0.01	0.01	0.01	0.01
CH_4 from FFC	<0.01	<0.01	<0.01	<0.01	<0.01
CO_2 from IP	0.20	0.19	0.01	0.01	0.01
CH_4 from IP	0.17	0.22	0.23	0.23	0.27
HFC/PFC/NF_3	0.00	0.04	0.07	0.04	0.04
Residential	**1.08**	**1.21**	**1.16**	**1.16**	**1.29**
CO_2 from FFC	1.07	1.19	1.03	0.90	0.86
N_2O from FFC	<0.01	<0.01	<0.01	<0.01	<0.01
CH_4 from FFC	0.01	0.01	0.01	0.01	<0.01
HFCs	<0.01	0.01	0.12	0.25	0.43
Commercial	**0.58**	**0.78**	**1.35**	**1.51**	**1.72**
CO_2 from FFC	0.58	0.73	1.10	1.20	1.35
N_2O from FFC	<0.01	<0.01	<0.01	<0.01	<0.01
CH_4 from FFC	<0.01	<0.01	<0.01	<0.01	<0.01
HFCs	<0.01	0.05	0.24	0.31	0.37
Agricultural	**0.61**	**0.54**	**0.58**	**0.62**	**0.64**
Enteric Fermentation	0.06	0.05	0.04	0.04	0.04
Manure Management	0.19	0.18	0.20	0.23	0.26
Ag Soils	0.36	0.30	0.33	0.34	0.33
Ag Residue Burning	<0.01	<0.01	<0.01	<0.01	<0.01
Liming and Urea	<0.01	<0.01	0.01	0.01	0.01
Waste Management	**0.59**	**0.49**	**0.51**	**0.44**	**0.48**

	1990	2005	2018	2030	2050
Wastewater Treatment	0.11	0.15	0.20	0.22	0.27
Landfill Activities	0.33	0.34	0.31	0.22	0.21
Waste Incineration	0.15	N/A	N/A	N/A	N/A
Land Use/Forestry	**0.09**	**-1.05**	**-0.86**	**-0.86**	**-0.86**
Gross GHG Emissions	**20.08**	**23.19**	**16.89**	**16.76**	**18.26**
Net GHG Emissions	**20.16***	**22.13**	**16.03**	**15.90**	**17.40**

*Net GHG emissions are greater than gross because the LULUCF sector was estimated to have positive emissions in 1990

Electric Power Sector

The emissions of GHGs in the electric power sector are driven by fossil fuel combustion for electricity generation. As stated in the **Updates** section, GHG emissions are estimated for both electricity generated and consumed in Delaware. Electricity is primarily generated both in and out of the state by the combustion of fossil fuels, like coal, natural gas, and petroleum products, to meet demand in Delaware. Renewable energy sources, like solar, also generate electricity that may be used in Delaware. The U.S. EPA SIT estimates GHG emissions associated with combustion for in-state electric power generation using fossil fuel consumption data from the U.S. EIA State Energy Data System (SEDS)[22] and emission factors for each fuel type. The SIT also has a module for estimating GHG emissions associated with electricity consumption. Data on electricity consumption per sector are sourced from the U.S. EIA SEDS.

Electric power generators that serve demand in Delaware operate on the regional power grid and are called upon to operate based on price offers to meet load. It would be nearly impossible to track which generators supply electricity to meet demand at a specific location. The overall estimate of GHG emissions associated with electricity consumption in Delaware would include some degree of emissions that are also counted for electricity generation. To avoid double counting emissions, it is assumed that electricity consumption needs in Delaware are first met by electricity generation within the state. The electricity demand activity data (in kWh) for Delaware was adjusted by subtracting the amount of in-state electricity generation (in kWh). Therefore, it would be expected that years with greater in-state generation would result in fewer relative emissions from consumption of electricity that is imported to Delaware.

Emission reductions associated with Delaware's RPS have been accounted for in this sector. Reductions were estimated based on the annual required percentage of electricity sourced from renewable energy. The RPS was amended in 2021 to achieve 40% of electricity in Delaware from renewable sources by 2035[23]. All years after 2035 held this requirement constant. Emission reductions were estimated assuming that the renewable energy has an emission factor of zero. A percentage of emissions corresponding to the percentage of renewable energy required each year was subtracted from the total electric power sector (emissions from in-state

[22] U.S. EIA, About SEDS; available: https://www.eia.gov/state/seds/
[23] Renewable Energy Portfolio Standards; available: https://dnrec.alpha.delaware.gov/climate-coastal-energy/renewable/portfolio-standards/

generation and electricity consumption). The reduction was applied uniformly across all fuel types in the case of in-state generation.

The EIA SEDS contains fossil fuel consumption data for electricity generation in Delaware. These fossil fuel consumption data are used to estimate the GHG emissions associated with power generation within the state. Each fossil fuel type has an associated carbon content which is used to estimate GHG emissions associated with the amount of the respective fossil fuel consumed for electric power generation. The SIT module for estimating emissions based on electricity consumption uses a calculated amount of electricity consumed in kWh as an input. To estimate emissions, an emission factor from the U.S. EPA Emissions and Generation Resource Integrated Database (eGRID) is applied, as well as a transmission loss factor[24]. The SIT module for electricity consumption is broken out into the residential, commercial, industrial, and transportation[25] sectors. The U.S. EIA SEDS provides the sectoral electricity consumption data.

To estimate the amount of emissions associated with the consumption of electricity in Delaware, the annual difference between electricity consumed and generated was calculated. As stated above, to avoid double counting of emissions, it was assumed that all generation in Delaware is first used to meet electricity demand in Delaware. The calculated difference is assumed to be the electricity consumption needs met by imported power, or electricity that is generated outside of Delaware. The percentage of imports varies year-to-year due to a variety of factors, but typically ranges between 30 to 55%. To separate the needs of electricity to each of the sectors, a sectoral percentage was calculated using EIA SEDS data. The breakdown of electricity demand per sector in 2018 can be seen in Figure 12. These percentages were calculated on the original total consumption data in each sector and applied to the electricity consumption met from imported power (i.e., the difference between total consumption and Delaware total generation). The sectoral total electricity demands were used as inputs to the SIT electricity consumption module to estimate GHG emissions.

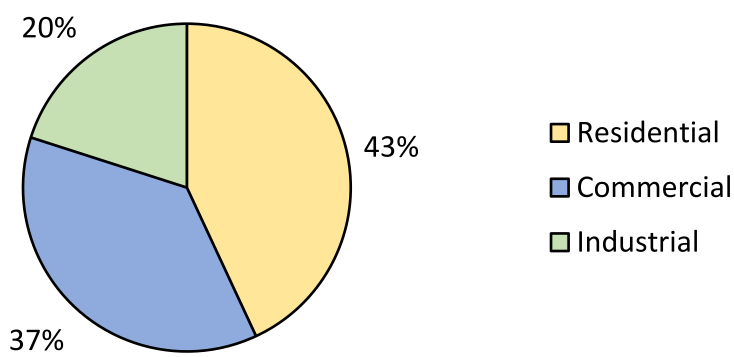

Figure 12. The percentage breakdown (by kWh) of electricity consumption per sector in Delaware in 2018

[24] U.S. EPA, Emissions & Generation Resource Integrated Database (eGRID); available: https://www.epa.gov/egrid
[25] Currently the electricity consumption data for the transportation sector in EIA SEDS is 0 for Delaware.

The total electric power sector GHG emissions are the sum of the GHG emissions associated with in-state electric power generation and electricity consumption (i.e., imported electric power) and the reduction of emissions associated with Delaware's RPS. The total electric power sector emissions account for 25% of Delaware's GHG emissions in 2018, which makes this sector the second largest source of GHG emissions in Delaware. Figure 13 shows the electric power sector GHG emissions from 1990 to 2018. There is an overall trend downwards in GHG emissions in the electric power sector; however, GHG emissions increased in 2018 for the first time since 2008. Total electricity demand in Delaware also increased in 2018, which contributed to the increase in emissions. Notably, GHG emissions from Delaware in-state electricity generation actually decreased in 2018. The increase in total demand caused the overall GHG emissions to increase, which was met with an increased amount of imported power. From climate data observed at the Dover station[26], it can be observed that the number of cooling degree days[27] increased by nearly 18% in 2018 relative to 2017. The number of cooling degree days in 2018 was also at its highest since 2011.

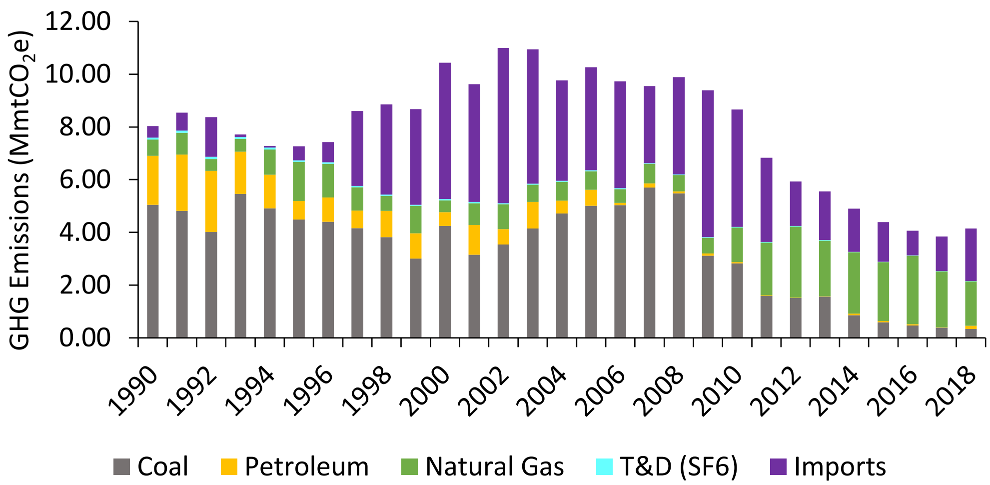

Figure 13. Greenhouse gas emission estimates in the electric power sector from 1990 to 2018 in Delaware; data shown by fuel type are representative to in-state generation, while consumption-based emissions from imported electricity is shown overall

Figure 13 shows that the emissions associated with imported electricity vary each year. In general, emissions associated with imported electricity range between 30 to 55%, with some years falling outside of the range. In 2018, the percentage of emissions from electricity imports was 48%, which is near the higher end of the range. As stated previously, the total electricity demand increased in 2018, while the total amount of in-state generation declined. Thus, the additional electricity demand was met with imported power. Despite electricity demand generally trending upwards with population over the time period, GHG emissions have an overall

[26] National Oceanic and Atmospheric Administration, National Centers for Environmental Information – Climate Data Online

[27] Cooling degree days are a measure of how hot the temperature was on a given day by comparing the mean outdoor temperature recorded for a given day to a standard temperature (typically 65°F).

downward trend. As the electric power grid adds more renewable energy and lower emitting resources, the overall carbon intensity of electricity in the grid declines.

Greenhouse gas emission projections in the electric power sector were estimated similarly to those between 1990 and 2018. Electricity generation projections were based on fossil fuel consumption estimates from the U.S. EIA AEO 2020. Electricity consumption projection data were also calculated using the U.S. EIA AEO 2020. Like the emission estimates from 1990 to 2018, it was assumed that electricity generated in Delaware is first used to meet the needs of in-state electricity demand. The difference between total electricity consumption projected and the in-state electricity generation projected was calculated to determine the electricity consumption demand met by imported power. Electricity consumption projections are separated by sector (residential, commercial, industrial, and transportation[28]). A percentage-based approach was used to separate the electricity consumption projections by sector using the sectoral electricity consumption as estimated in the U.S. EIA AEO 2020. As stated above, emission reductions associated with Delaware's RPS were projected assuming that the standards after 2035 were held constant at 40% through 2050.

The estimated electricity consumptions by sector were used in the Projection Tool to estimate the associated GHG emissions that would be sourced from imported power. The Projection Tool holds the emission factor for electricity consumption and the transmission loss factor constant through the projection period. It should be expected that the emissions estimates for earlier years of the projection period are more accurate, while later years may have more uncertainty as the regional grid continues to add more renewable energy and lower emitting resources.

Projected emissions in the electric power sector can be seen in Figure 14. Electric power sector GHG emissions are projected to be fairly constant throughout the projection period. Greenhouse gas emissions generally decrease through 2035, while the RPS is still increasing. After 2035, GHG emissions begin to trend upwards. It can be expected that after 2035, the reductions associated with the RPS are not keeping up with the increases in emissions associated with increased demand. The 2018 load forecast by PJM also shows minor increases in load for the DPL zone[29]. Through 2035, the increases are mitigated in part by the RPS, but it should also be expected that emissions are decreasing as the overall carbon intensity of electric power on the grid decreases. As described in the **Updates** section of this report, the projections are based on the U.S. EIA AEO 2020. Emissions impacts from stay-at-home orders and other actions during the COVID-19 pandemic are not captured here. It would be expected that an emissions decrease is observed for 2020 and some early years in the projection period.

[28] Transportation electricity consumption per AEO 2020 is 0 for DE. This is unlikely as EV adoption rises; however, additional modeling would be required to generate accurate projections.
[29] PJM Load Forecast Report January 2018; DPL zone also includes parts of Maryland and Virginia.

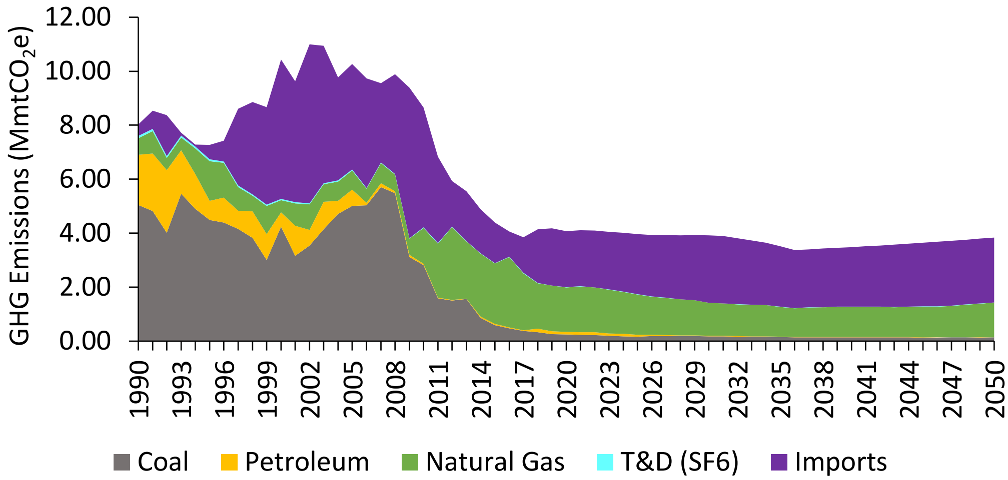

Figure 14. Greenhouse gas emissions and projections in the electric power sector from 1990 to 2050 in Delaware; data shown by fuel type are representative to in-state generation, while consumption-based emissions from imported electricity is shown overall

Transportation Sector

The transportation sector was the largest source of GHG emissions in Delaware in 2018, at 30% of the total GHG emissions. This is a continuing trend from the 2017 GHG inventory, when transportation was also the largest source of GHGs in Delaware. Greenhouse gas emissions in the transportation sector have been trending upwards since 2011 and, in 2018, reached their highest point since 2008.

Greenhouse gas emissions in the transportation sector are majorly sourced from the combustion of fossil fuels, and particularly the combustion of petroleum products. A minor amount of GHG emissions is sourced from alternate fuel vehicles, which use natural gas as a fuel. Figure 15 shows the annual GHG emissions in the transportation sector from 1990 to 2018 by fuel type. Fossil fuel combustion in on-road and non-road vehicles was the source of at least 97% for all GHG emissions in the transportation sector in 2018. The balance of GHGs each year is made-up of HFC emissions from air-conditioning systems. Overall, GHG emissions in the transportation sector have been relatively unchanged since 1990. Some increasing and decreasing trends can be observed in Figure 15 that are reflective of effects from factors such as rising and falling gasoline prices, population growth, and more.

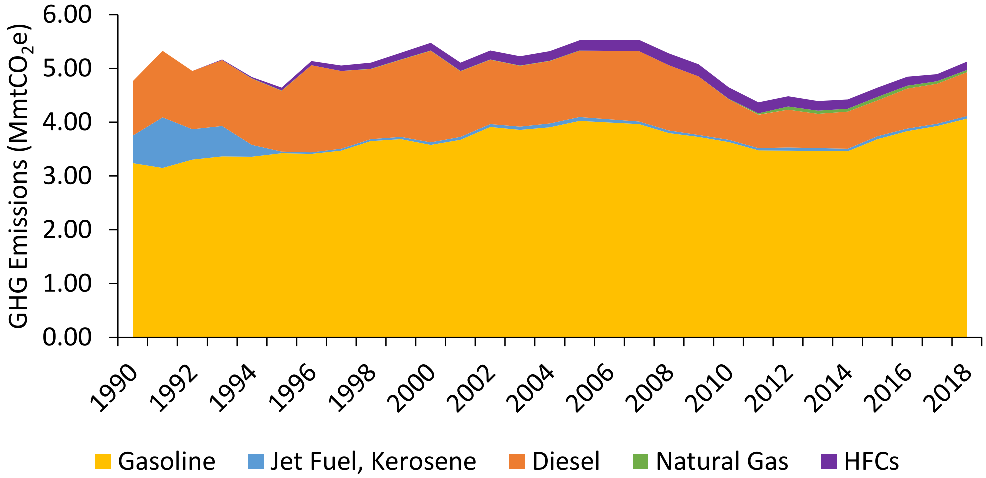

Figure 15. Greenhouse gas emissions in the transportation sector in Delaware from 1990 to 2018 by fuel type; HFC emissions shown are associated motor vehicle air-conditioning

Greenhouse gas emission estimates in the transportation sector can be disaggregated to the vehicle types that are the sources. The U.S. EPA SIT module for the transportation sector provides alternate calculations for CO_2 emissions based on an estimated vehicle fleet and vehicle miles traveled in Delaware. The alternate calculations are not used in the report to maintain consistent methodology with past GHG inventories. The estimates can be used to proportion GHG emission estimates that are generated using the U.S. EPA SIT standard methodology that is based on fossil fuel combustion data. This approach provides a simple estimate of the breakdown of GHG emissions by vehicle type and carries a degree of uncertainty. The estimates are useful to identify the major vehicle type sources of GHGs in Delaware, but they are not exact.

The relative fossil fuel combustion based GHG emissions by vehicle type can be seen in Figure 16. Emission estimates of HFCs represent the total transportation sector and are not separated out by vehicle type. Passenger cars have been the major source of GHG emissions in the transportation sector over the period of 1990 to 2018. The category also includes light-duty trucks and motorcycles. Heavy duty vehicles are the next highest source of GHGs in the transportation sector and show an increasing percentage of GHG emissions from 2011 to 2018. The Other category includes nonroad sources of GHG emissions such as aircraft and boats. This category shows a considerable decrease in emissions around the 2009 which can be related to the time of time economic recession; however, the reduced amount of GHG emissions never recovered to pre-recession levels. Construction vehicles were separated from the other category since they have been a consistent contributor of GHG emissions in the transportation sector through the period of 1990 to 2018.

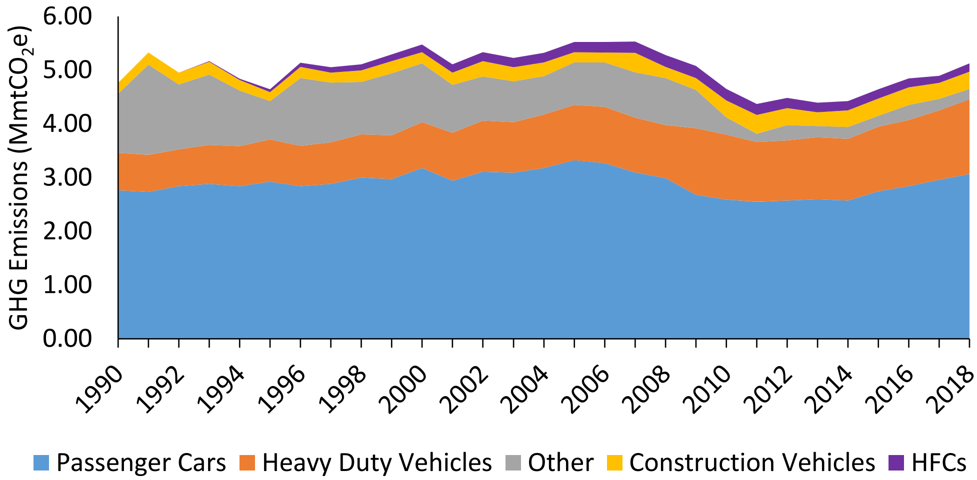

Figure 16. Greenhouse gas emissions from fossil fuel combustion disaggregated by vehicle type in Delaware from 1990 to 2018; HFC emissions are presented for the overall sector, not by vehicle type

Projections of GHG emissions are not disaggregated into individual vehicle type categories. This type of analysis would require in-depth modeling of projected vehicle fleet in the state. As shown in Figure 17, GHG emission projections in the transportation sector are displayed by fuel use. Gasoline is the dominant fuel type in the transportation sector, followed by diesel. Overall GHG emissions in the transportation sector are projected to gradually decrease in 2019 through about 2040, when emissions begin to slightly increase. The overall change in GHG emissions projected from 2018 to 2050 is a decrease of 0.32 $MmtCO_2e$, or about 6%.

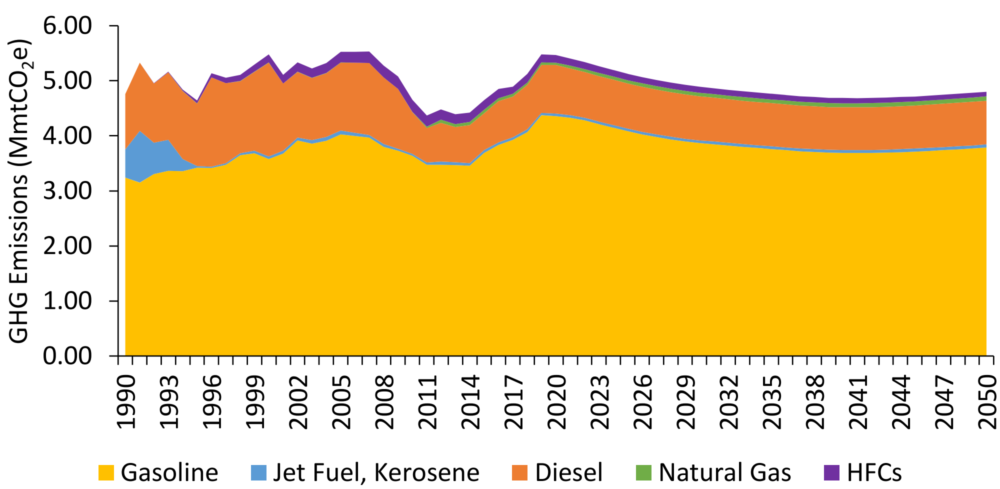

Figure 17. Greenhouse gas emissions and projections in the transportation sector in Delaware from 1990 to 2050 by fuel type; HFC emissions shown are associated motor vehicle air-conditioning

Industrial Sector

Industrial sector GHG emissions in Delaware are sourced from energy and non-energy related activities. The total industrial sector was the source of 24% of GHG emissions in the state of Delaware in 2018. This represents a decrease in the sectoral contribution for annual GHG emissions from 2017; however, the 2018 GHG inventory includes emissions associated electricity consumption. This addition caused the relative contribution of the industrial sector to overall GHG emissions to decrease. The actual 2018 GHG emissions in the industrial sector have had a slight increase of about 1% from 2017.

Greenhouse gas emissions from energy-related activities are those that are sourced from the direct combustion of fossil fuels, and they make up the majority of total industrial sector emissions. Emissions from non-energy related activities are those that are associated with industrial processes. Figure 18 shows the GHG emissions in the industrial sector broken out by fuel type for energy-related activities and non-energy emissions. Fossil fuel combustion in energy-related activities make-up about 92.5% of the total GHG emissions in the industrial sector in 2018. On average, GHG emissions from energy-related activities contribute 90% of the industrial sector emissions, with the notable exception in 2009 and 2010. Industrial sector GHG emissions had a steep decline that can be associated with the economic recession, loss of heavy industry, and the shut-down of the refinery operations from late-2009 to late-2011[30].

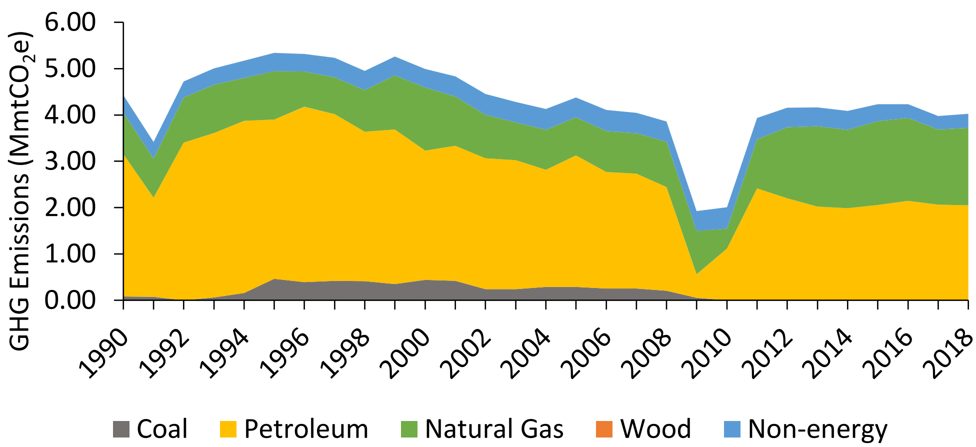

Figure 18. Greenhouse gas emissions in the industrial sector from 1990 to 2018 in Delaware; energy-related emissions are shown by fuel type, while non-energy emissions are provided overall

Wood burning for energy related activities contributes to <1% of annual industrial GHG emissions. The combustion of natural gas and petroleum products are the major sources of GHG emissions in the industrial sector in Delaware. Non-energy related activities include HFC emissions and fugitive emissions associated with refinery operations, natural gas transmission and distribution pipelines, and more.

[30] "PBF Celebrates Successful Restart of its Delaware City Refinery", Delaware News, Office of the Governor, October 2011

The industrial sector in Delaware is made up of a variety of chemical manufacturers, one petroleum refinery, poultry processing facilities, and other industries. Sources that meet applicable criteria are required to report GHG emissions to the U.S. EPA GHG Reporting Program[31]. It is noted that not all of Delaware's industrial sources meet these requirements and thus, do not report to the national program. Therefore, the data that are reported to the U.S. EPA GHG Reporting Program do not provide a complete inventory of Delaware's industrial sector GHG emissions. Further, the U.S. EPA GHG Reporting program only began collecting emissions data in 2010; thus, to remain consistent in reporting GHG emissions for the industrial sector, the SIT is used. The data can be useful in this timeframe, however, to proportion emissions by categories by using relative contributions to the total emissions reported from Delaware industrial sources to the U.S. EPA GHG Reporting Program. The major categories[32] identified among industrial sources identified in the data are refinery, chemicals, and other. The other category includes fossil fuel combustion-based emissions from operating equipment at poultry processing plants as well as emissions from institutional sources[33].

The proportioned GHG emission estimates from the industrial sector can be seen in Figure 19. The non-energy emissions shown are those that are provided by the SIT module for industrial sector GHG emissions. Emissions that were portioned out using the U.S. EPA GHG Reporting Program data were only energy-related emissions. As expected, the majority of GHG emissions in the industrial sector is sourced from petroleum refining operations, which is the most carbon-intensive industrial source. As explained, this representation of GHG emissions from the industrial sector in Delaware is an approximation based on a limited number of sources that report to the U.S. EPA GHG Reporting Program. It can be helpful to characterize the major sources of GHG emissions in the industrial sector; however, the data are simply estimates and carry a degree of uncertainty.

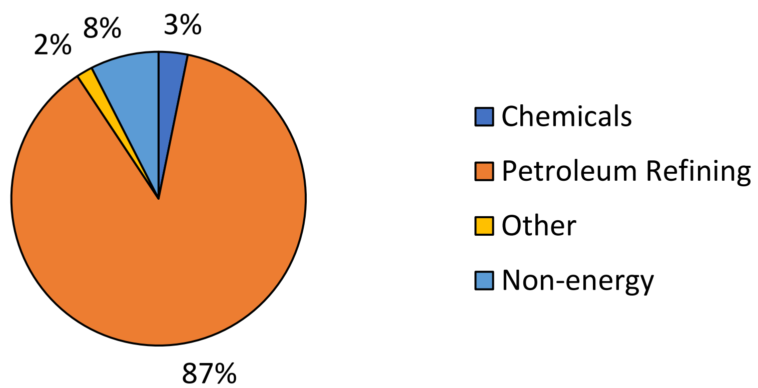

Figure 19. Greenhouse gas emissions in the industrial sector in 2018 disaggregated by subsectors in Delaware

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[31] U.S. EPA, Greenhouse Gas Reporting Program; available: https://www.epa.gov/ghgreporting

[32] The metals category is included from emissions data reported from steel processing which took place in Delaware through 2013. The chemicals category also included emissions associated with titanium dioxide manufacturing which took place through 2015.

[33] The only institutional source that reported to the U.S. EPA GHG Reporting Program in the time period was the University of Delaware.

Greenhouse gas emission projections in the industrial sector show a steady increase after 2018, as shown in Figure 20. Increased fossil fuel combustion, as projected in the U.S. EIA AEO, is the major cause of GHG emission increases in the industrial sector. Energy-related GHG emissions are projected to increase by 1.45 MMTCO$_2$e, or 39%. Non-energy emissions are projected to be essentially constant through 2050. Emission reductions associated with Delaware's HFC prohibitions for specific end uses mitigate projected increases of HFC emissions in the industrial sector.

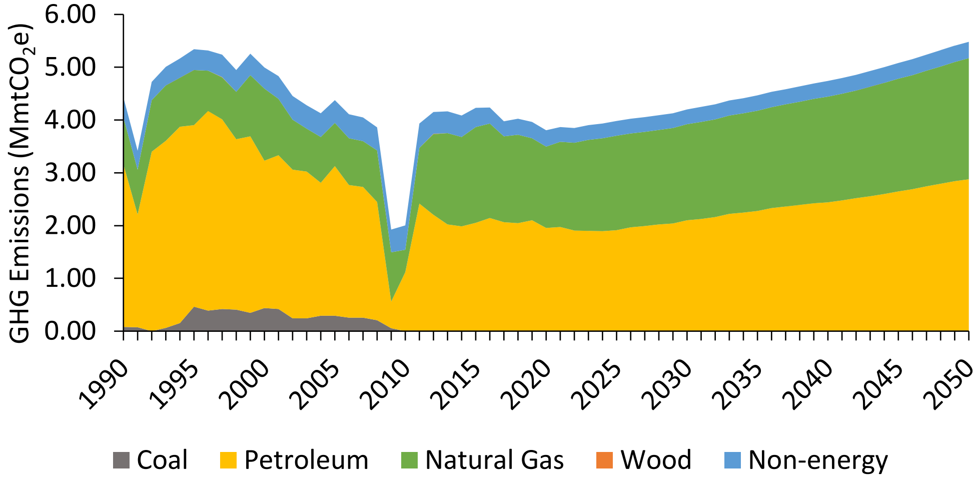

Figure 20. Greenhouse gas emissions and projections in the industrial sector from 1990 to 2050 in Delaware; energy-related emissions are shown by fuel type, while non-energy emissions are provided overall

Buildings Sector (Residential and Commercial)

As stated in the **Updates** section the residential and commercial sectors have been combined to be reported as a Buildings sector. This section will describe the GHG emissions associated with both the residential and commercial sectors. The GHG emissions presented cover those associated with fossil fuel combustion as well as HFCs. Greenhouse gas emissions associated with electricity consumption in these sectors are not included but are accounted for in the **Electric Power Sector** section of this report.

The overall buildings sector was the source of about 15% of GHG emissions in Delaware in 2018. The residential sector was 7% of the total GHG emissions, while the commercial sector was 8% of the total statewide GHG emissions. Figure 21 shows the overall GHG emissions in the combined buildings sector. There is an overall increasing trend in GHG emissions in the building sector in Delaware. In 2018, the sector was at its highest value. Some contributing factors may be population growth, weather, and others. More detail on each sector is provided in the following sections.

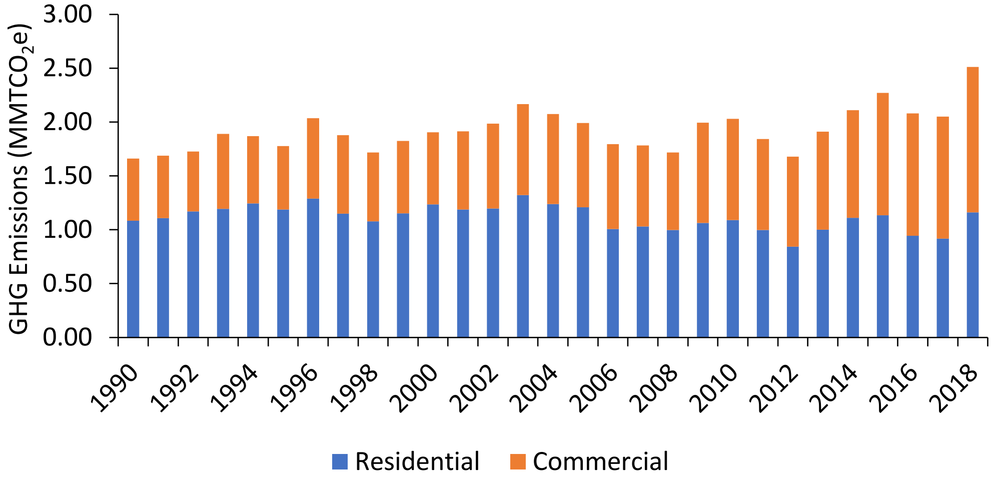

Figure 21. Greenhouse gas emissions from residential and commercial buildings in Delaware from 1990 to 2018

Residential Sector

Residential sector GHG emissions are estimated using energy consumption data and carbon content of each fuel type used. In addition, HFC emissions are estimated from residential refrigeration and air-conditioning.

Two primary uses of fossil fuels were identified for the residential sector to further categorize GHG emissions: space-heating and water-heating. To estimate the associated emissions, data from the U.S. EIA Residential Energy Consumption Survey (RECS)[34] were used to characterize relative fossil fuel use in each of these end uses. The most recent edition of the RECS data was published for 2015. These values were held constant from 2015 through 2018. Using these data and previous RECS data, the GHG emissions can be estimated for the base year and past years but cannot be used to project future emissions by end use. Data are not available at the state-level but were presented at the census division level. Thus, the GHG emissions per end use in the residential sector provide a good estimate but do contain a level of uncertainty.

The primary fuel type used in the residential sector in 2018 and more recent years is natural gas. As Figure 22 shows, historical emissions from 1990 to 2018 show some fluctuations that can be attributed to fuel switching as well as weather. For example, a local peak in the data in 1996 can be linked to temperature data at the Dover station. The year 1996 had the most days with a maximum temperature below 32°F between 1990 and 2018[35]. The increase in emissions in 2018 may also be linked to impacts from temperature. The number of heating degree days[36] increased by 14% in 2018 relative to 2017 and was the highest since 2015, when another peak in emissions can be observed.

[34] U.S. EIA, Residential Energy Consumption Survey (RECS); available: https://www.eia.gov/consumption/residential/
[35] National Oceanic and Atmospheric Administration, National Centers for Environmental Information – Climate Data Online
[36] Heating degree days are a measure of how cold the temperature was on a given day by comparing the mean outdoor temperature recorded for a given day to a standard temperature (typically 65°F).

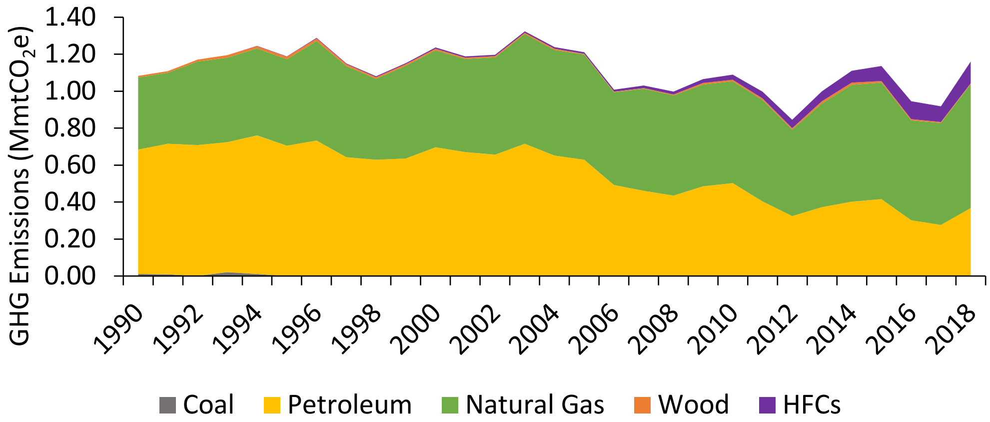

Figure 22. Greenhouse gas emissions in the residential sector in Delaware from 1990 to 2018; energy-related emissions are shown by fuel type, while HFC emissions are provided overall

While population in the state of Delaware increased during this time period, the overall emissions impact was likely mitigated by the trend in switching from petroleum (e.g., fuel oil, kerosene, and propane) to natural gas as a fuel for heating. The general shifting trend can be observed in Figure 22. A more in-depth assessment on particular end-uses in residential buildings can be observed in Figure 23. As can be seen, GHG emissions in the residential sector are primarily sourced from space-heating needs, which have undergone a transition from the majority associated with petroleum product use to natural gas. Greenhouse gas emissions associated with water-heating have been sourced primarily by natural gas use for the whole period of 1990 through 2018. While not shown here, it can be expected that a shift to electric appliances from systems that use petroleum products has played a role in decreasing emissions in the residential sector. The Other category in Figure 23 includes emissions associated with the use of natural gas and petroleum products in other applications, such as clothes dryers, cooking, and more. The Other category also includes the small amounts of wood and coal (coal use was minimal in the early inventory years), which were likely used for space-heating.

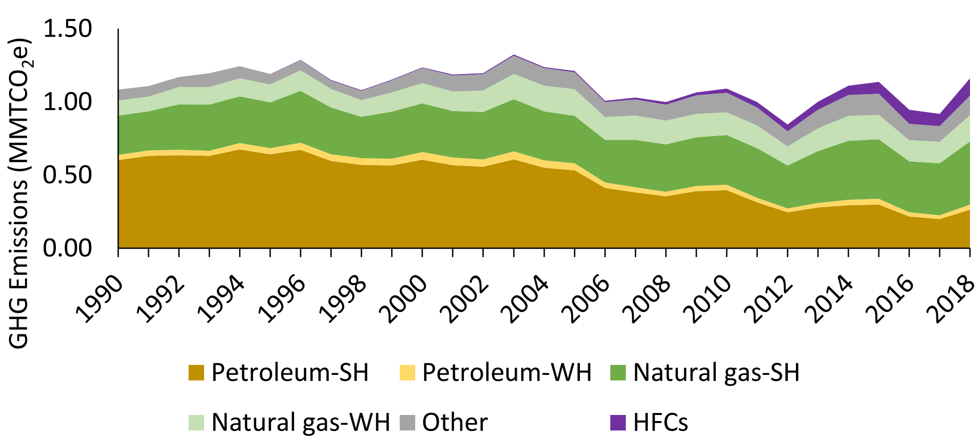

Figure 23. Greenhouse gas emissions in the residential sector in Delaware from 1990 to 2050 separated by end-uses; SH refers to space-heating, WH refers to water-heating

DNREC DIVISION OF AIR QUALITY

Greenhouse gas emissions in the residential sector are projected to slightly increase from 2019 to 2050, primarily caused by increases in HFC emissions (shown in Figure 24). By 2050, GHG emissions in the residential sector are projected to increase by 0.13 $MMTCO_2e$, or about 11%. The major source of GHG emissions projected in the residential sector continues to be the combustion of natural gas. While the end-uses cannot be disaggregated for the projected GHG emissions, the projections show that natural gas-based emissions remain constant. Petroleum-based emissions decrease through 2050. One possible reason for this may be a more significant portion of the residential sector switching from petroleum fuels for appliances to natural gas or electric replacements. Emissions of HFCs are projected to increase in the residential sector through 2050. It should be noted that Delaware's HFC prohibitions do not include the residential sector. Potential federal[37] action to limit sector-wide HFC emissions are anticipated; however, no HFC emission reductions were included for the residential sector.

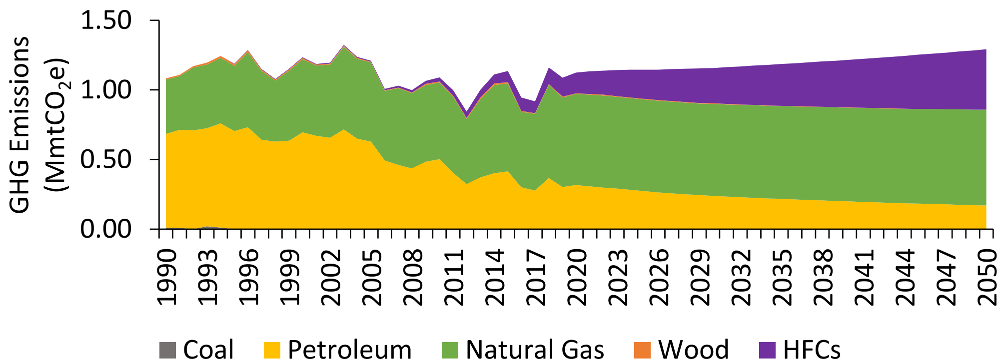

Figure 24. Greenhouse gas emissions and projections in the residential sector in Delaware from 1990 to 2050; energy-related emissions are shown by fuel type, while HFC emissions are provided overall

Commercial Sector

Commercial sector GHG emissions are estimated using energy consumption data and carbon content of each fuel type used. In addition, HFC emissions are estimated from residential refrigeration and air-conditioning. Emission reductions associated with Delaware's HFC prohibitions are included in the commercial sector for end-uses per their respective effective dates (earliest dates in 2021).

Like the residential sector, GHG emissions associated with space-heating and water-heating needs in the commercial sector were identified. Data from the U.S. EIA Commercial Buildings Energy Consumption Survey (CBECS)[38] were used to assess the relative fuel uses for each end use. The most recent edition of the CBECS was published for 2012 data[39]. Therefore, 2012 data have been held constant through 2018. The 2012 CBECS data and earlier editions were used to estimate GHG emissions by key end uses in the commercial sector from 1990 to 2018. As with

[37] U.S. EPA, Protecting Our Climate by Reducing Use of HFCs; available: https://www.epa.gov/climate-hfcs-reduction
[38] U.S. EIA, Commercial Buildings Energy Consumption Survey (CBECS); available: https://www.eia.gov/consumption/ commercial/
[39] The 2018 edition of the CBECS is planned to be available in spring 2022.

the RECS data, the CBECS data are only available at the census division level[40], not the state level. A degree of uncertainty should be considered with the emissions estimates.

Natural gas was the most prominent fuel used in the commercial sector. Greenhouse gas emissions in the commercial sector can be seen in Figure 25 for the years 1990 to 2018. Some fluctuations occur in the emissions estimates that are likely attributed to the changes in weather. A spike in emissions is observed in 2018, which can be linked to the increase in heating degree days in 2018. Natural gas related emissions became the majority by the mid-2000s, after being nearly on par with those associated with petroleum products in years prior. Commercial sector GHG emissions show an overall rising trend from 1990 through 2018.

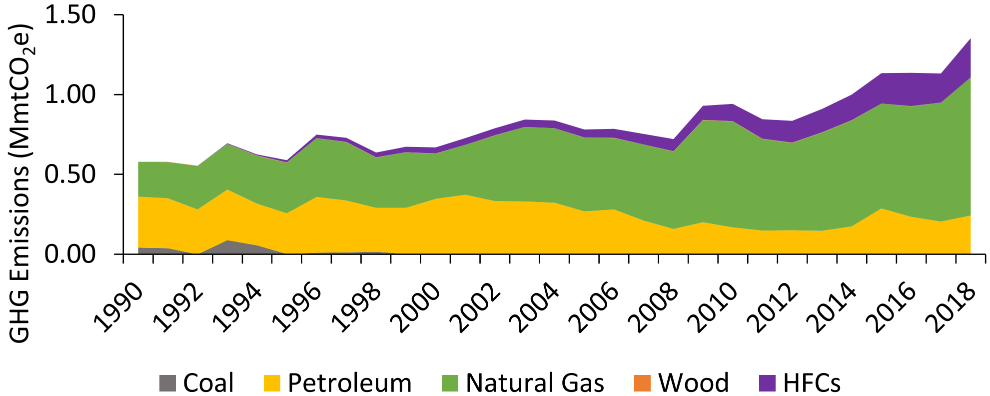

Figure 25. Greenhouse gas emissions in the commercial sector in Delaware from 1990 to 2018; energy-related emissions are shown by fuel type, while HFC emissions are provided overall

Space-heating applications were the highest contributor to GHG emissions in the commercial sector, as Figure 26 shows. Relative to the residential sector, a larger percentage of the overall GHG emissions in the commercial sector can be observed in the Other category. Natural gas and petroleum product use in other applications, especially in cooking, contribute to a significant portion of commercial sector GHG emissions. Figure 26 also shows the rapid rate of growth of HFC emissions in the commercial sector, which can be associated with increased refrigeration and air conditioning. Greenhouse gas emissions from petroleum product use in the commercial sector show an overall downward trend. Natural gas based GHG emissions show a rise in overall contribution from 1990 to 2018; however, a shift to electric appliances may also have contributed to declining petroleum product use.

[40] Prior to the 2003 edition of the CBECS, data were only available at the census region level; therefore, the 2003 CBECS data were held constant retrospectively through 1990

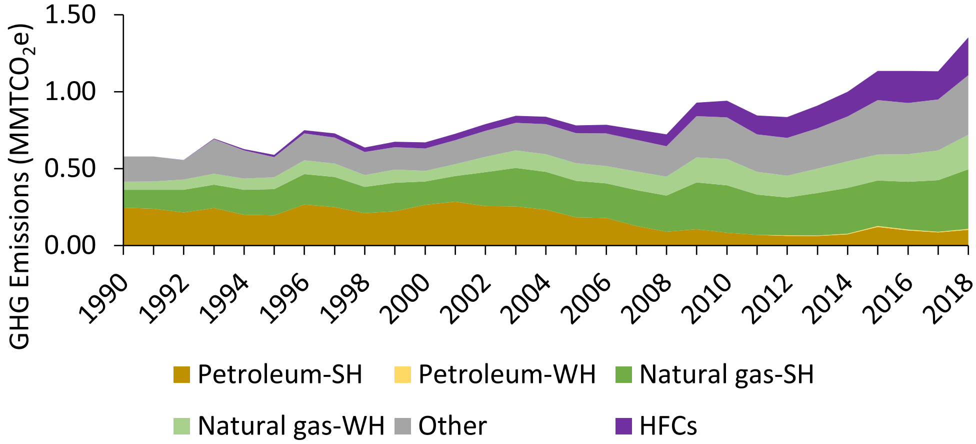

Figure 26. Greenhouse gas emissions in the commercial sector in Delaware from 1990 to 2050 separated by end-uses; SH refers to space-heating, WH refers to water-heating

Greenhouse gas emission projections in the commercial sector show an increasing trend. Figure 27 show the projected GHG emissions in the commercial sector from 2019 to 2050. Emissions associated with petroleum product combustion remains constant throughout the time period. A slight increase in GHG emissions associated with natural gas combustion is also observed. HFC emissions show an upward trend in the commercial sector, increasing by about 54% by 2050 compared to 2018. This increase in HFC emissions can be associated with increased usage of refrigeration and air-conditioning in the commercial sector; however, the increase in emissions is managed by Delaware's HFC prohibitions. Overall GHG emissions in the commercial sector are projected to increase by 27%. Some potential factors that have an effect on the amount of GHG emissions in the commercial sector may be the growing population and need for commercial applications of comfort cooling and refrigeration.

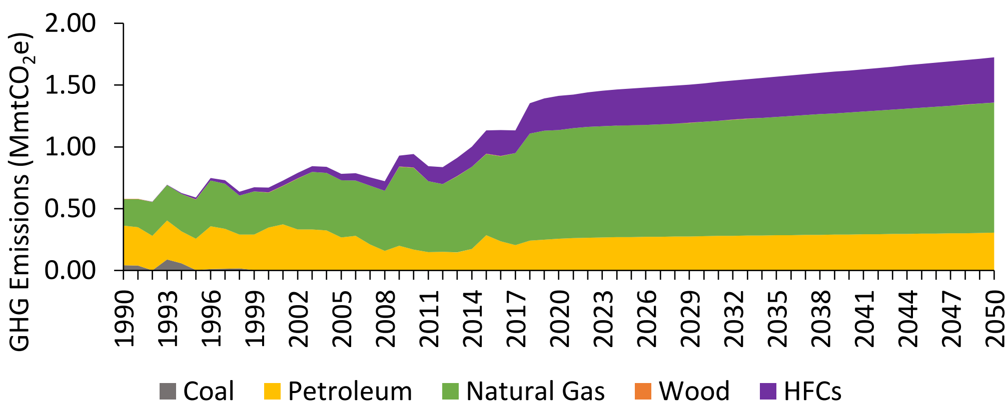

Figure 27. Greenhouse gas emissions and projections in the commercial sector in Delaware from 1990 to 2050; energy-related emissions are shown by fuel type, while HFC emissions are provided overall

Agricultural Sector

Agricultural sector GHG emissions represented approximately 3% of the total gross GHG emissions in Delaware in 2018. Greenhouse gas emissions from the agricultural sector have been essentially constant since 1990, as shown in Figure 28. Projections of GHG emissions are also expected to remain constant in the agricultural sector through 2050. Unlike other sectors, the major GHG emissions in the agricultural sector are N_2O and CH_4, not CO_2. The major sources of GHG emissions in the agriculture sector are associated with agricultural soil management and manure management. Agricultural soil management GHG emissions were all N_2O, and this source category contributed to 57% of the GHG emissions from the agricultural sector in 2018. Manure management GHG emissions were made up of both N_2O (76%) and CH_4 (24%) and contributed to a total of 35% of the total agricultural GHG emissions estimated in 2018. The remaining source categories make up less than 10% of the total GHG emissions for the agricultural sector in 2018. These trends for major emission sources in the agricultural sector continue throughout the projection period to 2050.

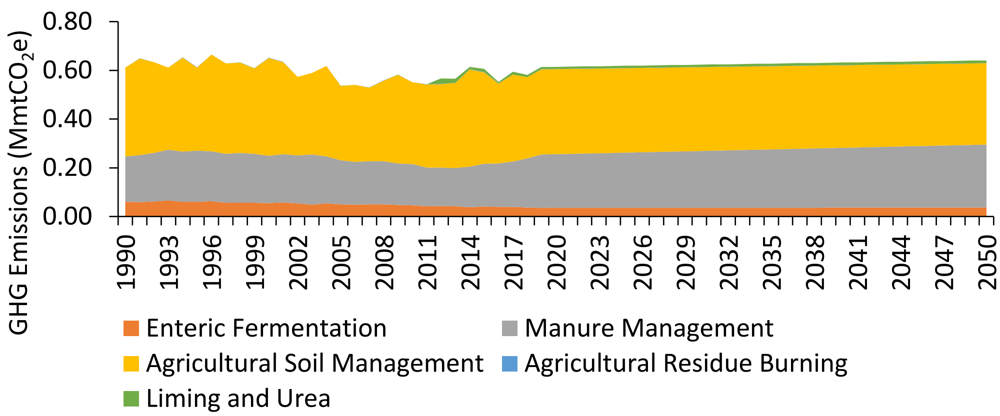

Figure 28. Greenhouse gas emissions and projections in the agricultural sector in Delaware from 1990 to 2050, separated by source categories

Waste Management Sector

Greenhouse gas emissions from the waste management sector include wastewater treatment CH_4 and N_2O emissions and municipal solid waste (landfill) CH_4 emissions. Greenhouse gas emissions from wastewater treatment were fairly constant from 1990 to 2018 and are based mainly on municipal wastewater and industrial wastewater from poultry processing. The majority of emissions in the waste management sector are fugitive methane emissions from municipal solid waste landfills. For completeness, historical GHG emissions associated with municipal waste combustion were included, but the practice was banned in 2000.

As Figure 29 presents, GHG emissions fluctuated from 1990 to 2018. Fluctuations in the waste management sector are largely based on changes in operation in the municipal solid waste sector. The first major change in emissions occurred between 1997 and 1998, when flaring began each of the three major landfills. In addition, land fill gas recovery for energy generation started in 1997 at the Cherry Island Landfill site. Energy generation from landfill gas began in 2007 at the Central and Southern Solid Waste Management Centers; however, additional decreases in emissions were not observed because processes simply shifted from solely flaring. A moderate increase in emissions can be observed in 2017 and 2018, due to a lower collection efficiency at one of the municipal solid waste landfill sites. Greenhouse gas emissions in the waste management sector are projected to remain constant from 2019 to 2050, assuming collection rates and efficiencies remain constant through 2050. Increases in GHG emissions associated with wastewater treatment is linked to population growth and continued poultry processing operations.

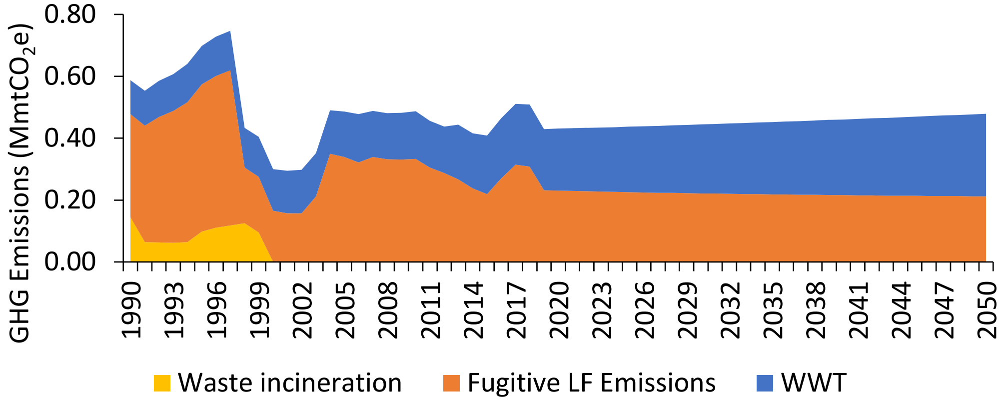

Figure 29. Greenhouse gas emissions and projections from the waste management sector in Delaware from 1990 to 2050 by source category; WWT refers to wastewater treatment

Land-use, Land Use Change and Forestry

The 2018 GHG emissions inventory identified the land-use sector as a sink[41] for GHG emissions in Delaware. Carbon emissions and/or sequestration in the land-use sector are calculated as the annual change in carbon storage among different carbon pools of Delaware's forest and croplands, as well as harvested wood products. Between 1990 and 1998, estimated emissions from the land use sector were positive. However, despite some losses in forest acreage, increased forest management practices and trees reaching maturity have enhanced carbon sequestration from 1999 to the present[42, 43]. In 2018, total GHG emissions for LULUCF sector were -0.86 $MmtCO_2e$; meaning, 0.86 $MmtCO_2e$ in GHG emissions were sequestered from the atmosphere to Delaware's land sector. This would be equivalent to offsetting about 5.1% of Delaware's gross GHG emissions in 2018. This is an increase in removal from the 2017 GHG inventory assessment of the LULUCF sector. The increase may be attributed to the change in methodology and updated data provided by the U.S. EPA, as detailed in the **Updates** section of this report. The removal of GHGs in this sector peaked in 2005 with a net GHG removal of 1.05 $MmtCO_2e$ as indicated in Figure 30. Since it is difficult to project sequestration of carbon and there is a significant amount of uncertainty, the projection analysis for this sector was based on the assumption that Delaware's change in carbon storage will remain constant from 2018 to 2050 at 0.86 $MmtCO_2e$.

[41] A sink is the removal of GHG from the atmosphere
[42] Delaware Forest Resource Assessment, Delaware Forest Service, 2010
[43] Delaware Forests 2013, United States Forest Service, 2017

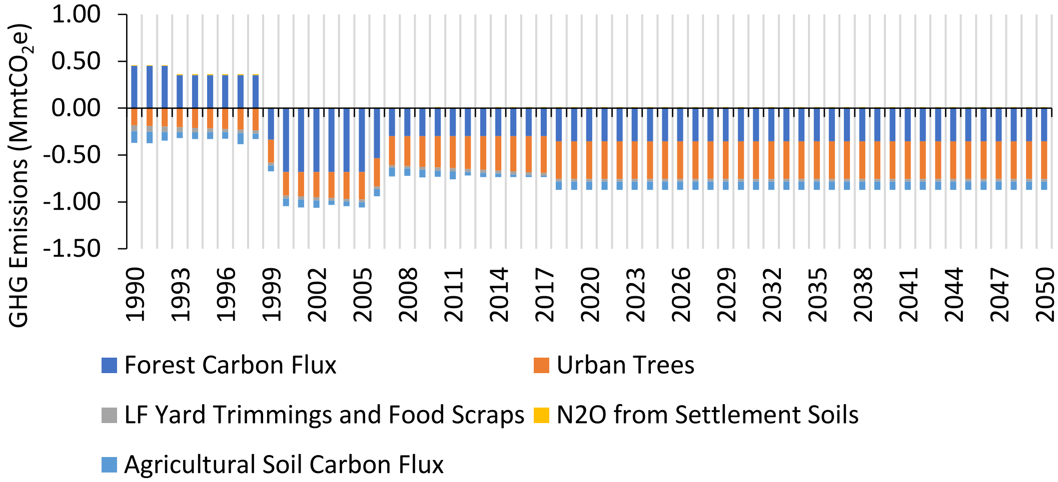

Figure 30. Greenhouse gas emissions, sequestration (represented as negative emissions), and projections of carbon (in MmtCO$_2$e) in the LULUCF sector in Delaware from 1990 to 2050; LF refers to landfills

Conclusions

Overall, GHG emissions in 2018 in Delaware have increased from 2017 by about 6.4%. The 2018 GHG Inventory includes various additions and updates to the previous report, including accounting for emissions associated with electricity consumed in Delaware and emission reduction estimates from current policies. With these inclusions, Delaware is set to reach it's 2025 emission reduction target of 26-28% by 2025 from 2005 levels. However, GHG emission projections show that a declining trend is not expected through 2050. By the mid-2040s, Delaware GHG emissions are expected to fall short of the 26% reduction target and continue to increase through 2050. As Delaware is already experiencing harmful impacts from the effects of climate change, it is important to continue to reduce GHG emissions. Further policy may be needed to continue to have meaningful mitigation of GHG emissions in the state. Like past reports, the three largest emitting sectors in Delaware are electric power, transportation, and industry. The electric power sector has been showing significant declines from shifts to lower emitting combustion fuels and zero-emitting sources of power. The transportation sector remains consistent in GHG emissions, showing a trajectory that averages out to a flat line from current levels. The industrial sector is projected to continue to increase in GHG emissions through 2050, becoming the largest sector of GHG emissions in Delaware. The transportation and industrial sectors are major sectors to look to emissions reductions for a meaningful effect on overall emissions reductions in Delaware.